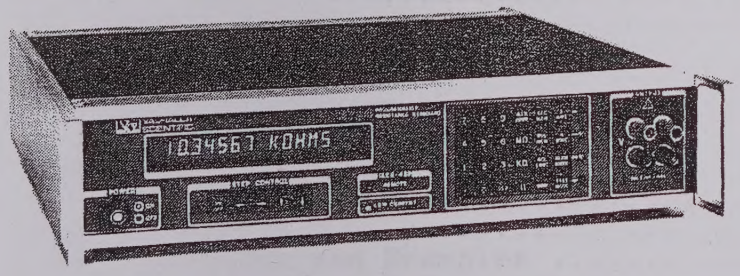
2724A / CPR

PROGRAMMABLE PRECISION RESISTANCE STANDARD

OPERATION AND MAINTENANCE MANUAL



VALHALLA SCIENTIFIC, INC.
9955 MESA RIM ROAD
SAN DIEGO, CA 92121
(619) 457-5576 - TELEX 181750

Revised 9/86

Digitized by the Internet Archive
in 2026

https://archive.org/details/manualsplus_11669

TABLE OF CONTENTS

SECTION I - UNPACKING AND INSTALLATION

1.1	Unpacking and Inspection	1-1
1.2	Initial Adjustments	1-1
1.3	Instructions for Bench Use	1-1
1.4	Instructions for Rack Mounting	1-1
1.5	Safety Precautions	1-2

SECTION II - SPECIFICATIONS 2-1

SECTION III - MANUAL OPERATION

3.1	General	3-1
3.2	Connections	3-1
3.2.1	Four-Wire Connections	3-1
3.2.2	Two-Wire Connections	3-4
3.3	Numeric Value Entry	3-4
3.4	Step Control	3-5
3.5	Memories	3-5
3.6	Two-Wire/Four-Wire Selection	3-6
3.6.1	2724A Without CPR	3-6
3.6.2	2724A With CPR	3-6
3.7	Slow-Mode and Fast-Mode (2724A Without CPR)	3-7
3.8	Two-Wire Key (2724A With CPR)	3-7
3.9	Fast-Mode Key (2724A With CPR)	3-8
3.10	Card PNT Key	3-8
3.11	PPM DEV Key	3-9

SECTION IV - IEEE-488 INTERFACE OPERATION

4.1	IEEE-488, An Explanation Of The Bus	4-1
4.2	Definitions	4-1
4.3	General	4-3
4.4	Simple Commands and Examples	4-5
4.5	Advanced Commands and Examples	4-7
4.6	SRQ, Serial Poll and Parallel Poll	4-8

SECTION V - THEORY OF OPERATION

5.1	General	5-1
5.2	Functional Description	5-1
5.3	Detailed Circuit Descriptions	5-1
5.3.1	Reference Resistors	5-1
5.3.2	REF Buffer	5-2
5.3.2.1	Unit Gain Buffer	5-2
5.3.2.2	Ohms Multiplier	5-3
5.3.3	Variable Gain Amplifier	5-3

TABLE OF CONTENTS (Cont.)

5.3.3.1	MDAC's	5-3
5.3.3.2	Output Buffer	5-4
5.3.4	A/D Convertor	5-4
5.3.4.1	Pre-Scaling and Input Multiplexing	5-4
5.3.4.2	Reference Voltage Generator	5-5
5.3.4.3	FET Switch Drives	5-5
5.3.4.4	Current Balance	5-5
5.3.5	Floating Section Isolation	5-5
5.3.6	Microprocessor	5-6
5.3.6.1	A/D Convertor Logic	5-6
5.3.6.2	Opto-Isolator Latches/Drivers	5-6
5.3.6.3	Microprocessor (MPU)	5-6
5.3.6.4	Address Decode	5-8
5.3.6.5	Memory	5-8
5.3.7	Clock, Display and Keyboard	5-8
5.3.8	IEEE-488 Interface	5-9
5.3.9	Power Supplies	5-9

SECTION VI - CALIBRATION AND MAINTENANCE

6.1	A Brief Description of the Calibration Procedure	6-1
6.2	General	6-2
6.3	Calibration	6-3
6.3.1	Step 1 (Non CPR units)	6-2
6.3.2	Step 2 (Non CPR units)	6-2
6.3.3	2724 CPR Adjustment Procedure	6-3
6.3.4	Front Panel Calibration	6-5
6.3.5	Step 3 Active Mode Calibration (all units)	6-6
6.3.6	Step 4 CPR Calibration (option CPR only)	6-9
6.4	Step 5 - Completion of Calibration	6-9
6.5	Automatic Calibration	6-10
6.6	Troubleshooting	6-10

SECTION VII - AVAILABLE OPTIONS

7.1	General	7-1
7.2	Option TL-1	7-1
7.3	Option RX-3	7-1
7.4	Option BBL	7-1
7.5	Options GP1, GP2	7-1
7.6	Calibration Kit M24	7-1
7.7	Option CPR	7-1
7.8	SP-2	7-1

SECTION VIII - USEFUL HINTS

8.1	General	8-1
8.2	Unstable Test Currents	8-1

TABLE OF CONTENTS (Cont.)

8.3 Wheatstone Bridge Comparison to Standard Resistors 8-1
8.4 Use With High Resistance Meters 8-2

8.5 Use With Active Feedback Current Sources 8-2
8.6 Line Interference 8-2
Additional Helpful Hints 8-3

SECTION IX - DIAGRAMS

9.1 General 9-1

SECTION X - PARTS LISTS

10.1 General 10-1

LIST OF TABLES

1-1. Voltage Switch Settings and Fuse Ratings 1-1

2-1. General Specifications 2-1
2-2. Operating Specifications 2-2

3-1.(a) Front Panel Controls (2724A and 2724CPR) 3-2
3-1.(b) Front Panel Controls (2724A Without Option CPR) .. 3-3
3-1.(c) Front Panel Controls (2724A With Option CPR) 3-3
3-2. Error Message Displays 3-4

4-1. ASCII Character and Bus Messages 4-4
4-2. SRQ Bit Patterns 4-9

6-1. Troubleshooting Guide 6-8

LIST OF ILLUSTRATIONS

Figure 3-1 Slow Mode Equivalent Circuit 3-6
Figure 3-2 Fast Mode Equivalent Circuit 3-7
Figure 3-3 CPR Mode Equivalent Circuit 3-8

Figure 6-1 Calibration Connections 6-4

SECTION I - UNPACKING AND INSTALLATION

1.1 UNPACKING AND INSPECTION

If the shipping carton is damaged, request that the carrier's agent be present when the unit is unpacked. If, when unpacked, the unit shows external damage, the carrier's agent should authorize repairs before the unit is returned to the factory. If the shipping carton is damaged, the unit may have suffered internal damage in transit that may not be evident until the unit is operated or tested to verify conformance with its specifications. If the unit fails to perform or fails to meet the performance specifications of Section II, notify the carrier's agent and the nearest Valhalla Sales Office. Retain the shipping carton for the carrier's inspection. DO NOT return equipment to Valhalla Scientific or any of its sales offices prior to obtaining authorization to do so.

1.2 INITIAL ADJUSTMENTS

The only adjustments required before placing the unit in operation are to set the rear panel switch to the local power voltage and verify that the proper fuse is installed as listed in Table 1-1.

Table 1-1. Voltage Switch Settings and Fuse Ratings.

SUPPLY VOLTAGE	SWITCH SETTING	FUSE RATING
104 - 127	115	0.5 Amp Slo Blo
208 - 254	230	0.2 Amp Slo Blo

1.3 INSTRUCTIONS FOR BENCH USE

The unit is delivered with all required hardware for bench use installed and special instructions for use in that manner are not necessary. However, before connecting the unit to the local power source, verify that the power cord is equipped with a three-terminal connector (see the Safety Instructions of paragraph 1.5).

1.4 INSTRUCTIONS FOR RACK MOUNTING

Optional brackets are available for mounting the Model 2724A in an equipment rack. These are listed in Section VII. The size of the unit and the location of its center of gravity dictate that it should be supported on both sides along its entire length through the use of "trays" or slides. If it is to be

transported while mounted in a rack, it should be supported such that movement in any axis is not possible.

Note that the specifications listed in Section II indicate that accuracy of the unit is degraded at abnormally high temperatures. Therefore, it is recommended that "spacer" panels at least 1.75 inches high be installed between this and any other units in the rack to insure freedom of air flow. Under no circumstances should the ambient air temperature around the unit exceed 50°C while the unit is in operation or 70°C when power is removed.

1.5 SAFETY PRECAUTIONS

The power plug should be a three-contact device and should be inserted only in a three-contact mating socket where the third contact provides a ground connection. Where power is provided through an extension cable with several outlets, the ground connection must be continuous. Any discontinuity in the ground lead may render the unit unsafe for use.

SECTION II - SPECIFICATIONS

The operating specifications for the 2724A are listed in table 2-2.

The environmental specifications are listed below in Table 2-1.

Table 2-1: General Specifications

Dimensions:	89mm (3.5 in) H x 432mm (17 in) W x 432mm (17 in) D
Weight:	7.2kg (16 lb) net, 10.5kg (23 lb) shipping
Power:	115/230 VAC $\pm$ 10% at 48 to 440 Hz, 30 VA
Temperature:	0 to 50C - Operating -30 to 70C - Storage
Humidity:	5 to 70% RH (non-condensing)

Table 2-2: Operating Specifications

Accuracies below are relative to NBS traceable standards and are valid at +5°C from calibration temperature within 15°C to 30°C. Add 21ppm for absolute accuracy utilizing Valhalla's production calibration traceability uncertainties.

2724A Active Mode Operation

Resistance in Ohms	Current Min.	Current Max.	Accuracy (for 90 Days) ±5°C)	Stability (DC to 1Hz) 24 Hr.	Stability 1 Year	Temperature Coefficient in ppm/°C	Setting Time in seconds: Change in Current	Setting Time in seconds: Change in Value
0 to 120	500μA	120mA	7ppm+2mΩ	2ppm	10ppm	1.5	2	2
120 to 1.2K	50μA	12mA	7ppm+7mΩ	2ppm	10ppm	1.5	2	2
1.2K to 12K	5μA	1.2mA	7ppm+50mΩ	2ppm	10ppm	1.5	2	2
12K to 120K	500nA	120μA	7ppm+500mΩ	2ppm	10ppm	1.5	2	2
120K to 1.20M	50nA	12μA	12ppm+5Ω	2ppm	10ppm	3	2	2
1.2M to 12M	5nA	1.2μA	20ppm+50Ω	2ppm	15ppm	5	3	2
12M to 120M	500pA	120nA	40ppm+1KΩ	500Ω	50ppm	15	4	2
120M to 1.2G	50pA	12nA	0.1%+50KΩ	50KΩ	0.05%	15	6	3
1.2G to 11G	5pA	1.2nA	0.1%+5MΩ	5MΩ	0.05%	15	15	5

Table 2-2: Operating Specifications (Continued)

2724A Fast Mode Operation (Active)

Resistance in Ohms	Current pk. max.	One Year ±5°C Absolute Accuracy in Ohms	Temperature Coefficient in Ohms/°C	Setting Time in milliseconds		0.05% Error Frequency
				Change in Current	Change in Value	
0 to 120	120mA	0.04	0.006	0.1	5	3KHz
120 to 1.2K	12mA	0.4	0.06	0.1	5	3KHz
1.2K to 12K	1.2mA	4	0.6	0.1	5	3KHz
12K to 120K	120μA	40	6	0.2	5	2KHz
120K to 1.2M	12μA	400	60	1	5	500Hz
1.2M to 12M	1.2μA	6K	600	10	10	50Hz
12M to 120M	120nA	60K	6K	500	100	--
120M to 1.2G	12nA	600K	60K	5 Sec.	2 Sec.	--
1.2G to 11G	1.2nA	6M	600K	15 Sec.	5 Sec.	--

Table 2-2: Operating Specifications (Continued)

2724A CPR Mode Operation (Slow or Fast Modes)

Resistance in Ohms	Current Max.	Accuracy (for 90 days ±5°C)	Stability (DC to 1Hz)		Temperature Coefficient in ppm/°C	Settling Time in Milliseconds	
			24 Hr.	1 Year		Fast Mode	Slow Mode
100	120mA	7ppm+2mΩ	2ppm	10ppm	1.5	0.1	100
1K	12mA	7ppm+7mΩ	2ppm	10ppm	1.5	0.1	100
10K	1.2mA	7ppm+50mΩ	2ppm	10ppm	1.5	0.1	100
100K	120µA	7ppm+500mΩ	2ppm	10ppm	1.5	0.1	100
1M	12µA	12ppm+5Ω	2ppm	10ppm	3	0.3	1 Sec.
10M	1.2µA	20ppm+50Ω	2ppm	15ppm	5	3	5 Sec.

Output Configuration: 2-wire/4-wire, front and rear terminals standard.

Leakage Current: ± 2pA ± 0.2pA/°C

Power Coefficient: 0.15ppm/mW

Noise and Thermals: (DC to 10Hz, 4-terminal)
CPR Mode ± 2uV Maximum
Standard Mode ± 4uV Maximum
Fast Mode ± 30uV Maximum

Maximum Input: 25V peak or 120mA (if option CPR installed: 15mA maximum in active modes)

Warm-up Time: 15 minutes to within 5ppm of final value

SECTION III - MANUAL OPERATION

3.1 GENERAL

The Model 2724A is equipped with front panel controls listed in Tables 3-1(a), (b) and (c).

A more complete description of key functions is provided in the following paragraphs.

Upon initial application of power, the unit performs various self-check procedures resulting in possible fault messages. If the self-check is satisfactory, the display will greet the operator with "HI THERE". ("HELLO", "GUTEN TAG", "BONJOUR" or a greeting message in another language may appear on units shipped outside the United States). Approximately one-second later either "2724A V-FB" or 2724CPR V-FB" will be displayed. Approximately one-second later, "CAL DATA OK" will appear in the display. If the self-check determines that a fault exists, an error message will appear in the display. Some of the messages are listed in Table 3-2. If the unit has the IEEE option installed, the address will be displayed for one second.

3.2 CONNECTIONS

The Model 2724A is a four-wire instrument. It is equipped with separate terminals for connection of the current source and voltage measurement leads of the measuring instrument. However, it may be used as a two-wire instrument as well. Directions for use in both modes are included in following paragraphs.

CAUTION

> The 2724A provides rear panel connectors wired in parallel with those on the front panel. Under no circumstances should connections to the front and rear panels exist at the same time.

3.2.1 FOUR-WIRE CONNECTIONS

When the Model 2724A is used with a four-wire measuring instrument, the current source leads of the measuring instrument should be connected to the "I" terminals of the 2724A. The voltage measuring leads should be connected to the "V" terminals. The 2724A can accommodate either polarity. However, care should be exercised to ensure that both leads connected to a pair of like colored terminals on the 2724A are of the same polarity.

Table 3-1(a). Front Panel Controls (2724A and 2724CPR)

MARKING	FUNCTION
ON/OFF	Selects/deselects digit step mode (See 3.4)
←	Shifts controlled decade up one decade (See 3.4)
→	Shifts controlled decade down one decade (See 3.4)
↑	Increments selected decade (See 3.4)
↓	Decrements selected decade (See 3.4)
Ø to 9 and .	Used for numerical entry of data (See 3.3)
CLR	Resets displayed value (during entry) (See 3.3)
MAN	Selects manual control (if enabled) (See 4.3)
STO MEM	Stores present value in one of 1Ø memories (See 3.5)
RCL MEM	Recalls value stored in one of 1Ø memories (See 3.5)
RCL LAST	Recalls last value (See 3.5)
Ω	Pressed at end of entry to indicate unit ohms (See 3.3)
KΩ	Pressed at end of entry to indicate kilohms (See 3.3)
MΩ	Pressed at end of entry to indicate megohms (See 3.3)
IEEE ADDR	Allows the IEEE unit address to be displayed or changed (See 4.3)

Table 3-1 (b)

Front Panel Controls (2724A Without Option CPR)

MARKING	FUNCTION
2 WIRE	Selects 2-wire offset compensation (See 3.6.1)
4 WIRE	Selects for no 2-wire compensation (See 3.6.1)
SLOW MODE	Selects for "Slow mode" operation (See 3.7)
FAST MODE	Selects for "Fast mode" operation (See 3.7)

Table 3-1 (c)

Front Panel Controls (2724A with Option CPR)

MARKING	FUNCTION
2 WIRE	Alternately (de)selects 2-wire compensation (See 3.6.2 and 3.8)
FAST MODE	Alternately selects Fast or Slow modes (See 3.9)
CARD PNT	Alternately selects CPR or Active modes (See 3.10)
PPM DEV	Allows for computation of UUT error (See 3.11)

Table 3-2. Error Message Displays.

MESSAGE	MEANING
All decimal points illuminated	ROM failure
All horizontal middle elements illuminated.	RAM failure
OUT OF CAL	Component out of tolerance
CAL DATA BAD	Data corrupted (requires calibration)
CLOCK FAILURE	Faulty clock circuit
MATH OVERFLOW	Contact Valhalla Service Office if this occurs
CANNOT CONTROL	See maintenance Section VII
MEMORY DATA BAD	Memory data corrupted
SETTLING	This is not an error message, but an indication that the instrument has not stabilized since new data was entered.
ATOD TIMEOUT	If this message persists or flashes then refer to maintenance Section VII.

3.2.2 TWO-WIRE CONNECTIONS

When the measuring instrument has only two wires, they should be connected to the "I" terminals of the 2724A. In such cases, to minimize measurement errors, the leads should be as short as possible, especially if the resistance to be measured is in the order of a few ohms. The two-wire mode should be selected to compensate for zero errors.

3.3 NUMERIC VALUE ENTRY

To select a resistance value for the output of the Model 2724A, the keys marked with "Ø" through "9", ".", "CLR", "Ω", "KΩ", and "MΩ" are used. The following examples illustrate the procedure:

To select 11.458 Ohms Press 1 1 . 4 5 8Ω

To select 1Ø5 M Ohms Press 1 Ø 5 MΩ

As the numbers are entered, they appear in the display. Pressing the "Ω", "KΩ" or "MΩ" key terminates the entry. Should an error be made during entry and before the "Ω", "KΩ"

or "MΩ" keys are pressed, pressing the CLR key will return the display to zero. Resistance values may be entered in any form. For example, 9ØØΩ,Ø.9KΩ , and Ø.ØØØ9 MΩ are valid entries for 9ØØ ohms.

3.4 STEP CONTROL

Any digit of a previously completed entry may be altered using the step control feature which is selected with the STEP CONTROL ON/OFF key. The least significant digit is initially selected for alteration. However, the keys with the left and right arrows enable the selection of other digits for alteration without affecting any of the other digits except for carry or borrow. The selected digit flashes. The keys with the up and down arrows increment and decrement the digit. If a cardinal point (Ø) is traversed, the unit automatically maintains the same digit for control, but alters higher or lower digits as necessary.

There are some points to remember:

1. The STEP CONTROL ON/OFF control is used to enter and exit the step control mode. The indicator in the key is illuminated when the mode is active.

2. The minimum resistance is Ø ohms. Attempting to step below zero will cause Ø ohms to be selected. Similarly, the maximum resistance is 1Ø.99999G Ohms.

3. Numeric entry will abort step-control and vice-versa.

3.5 MEMORIES

The Model 2724A has two types of user controllable memories:

1. Last Value Memory -- The unit automatically stores the last entered value, which may be recalled when not in the step control mode by pressing the RCL LAST key. A very useful feature of this control is that it exchanges the last and present values. Thus, if two resistance values need to be repetitively exchanged, pressing the RCL LAST (RECALL LAST) key will cause the unit to alternate between the two values. Note that only numerical values are stored.

2. User Definable Memory -- Any value presently in the display may be stored by pressing the STO MEM (STORE MEMORY) key and the appropriate digit key. The digit key selects one of ten memories (Ø through 9) in which the data will be stored. The contents of the memories may be recalled at any time. Press the RCL MEM key and the digit key that corresponds to the memory from which data is to be recalled.

Some points to remember:

1. The data is stored in non-volatile memories. Therefore, the data stored prior to shutdown will be in memory when power is again applied. The non-volatile memory is useful in ATE applications where the same values may be used over a period of days or weeks.

2. The value previously stored in memory location Ø is used as the initial value upon application of power.

3.6 TWO-WIRE/FOUR-WIRE SELECTION

3.6.1 2724A WITHOUT CPR

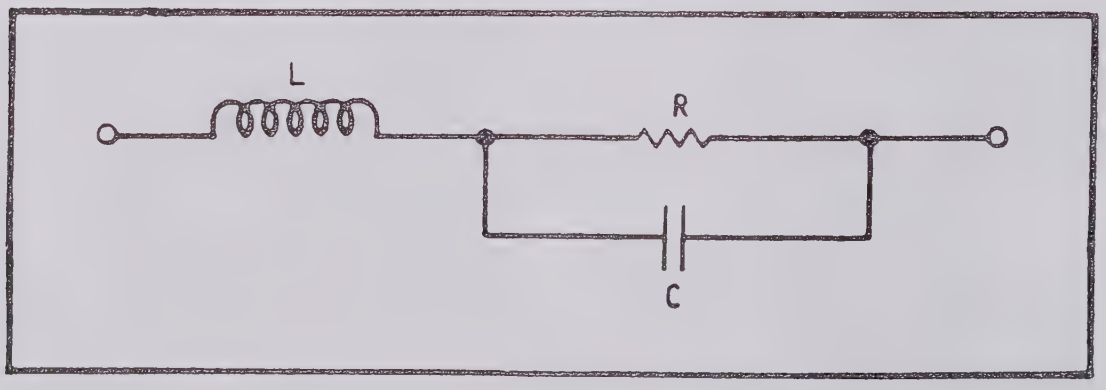
The two keys marked 2 WIRE and 4 WIRE are used (the adjacent LED indicating which mode is presently active).

In two-wire mode the unit actually outputs the displayed value less the calibrated two-wire offset.

3.6.2 2724A WITH CPR

The 2-WIRE key alternately switches between two-wire (LED on) and four-wire (LED off) modes. In two-wire active mode the unit outputs the displayed value less the calibrated two-wire offset. Whilst in CPR mode the displayed value is modified by the two-wire offset.

Figure 3-1. Slow Mode Equivalent Circuit



R = required resistance

L = R millihenries
(R is in ohms)

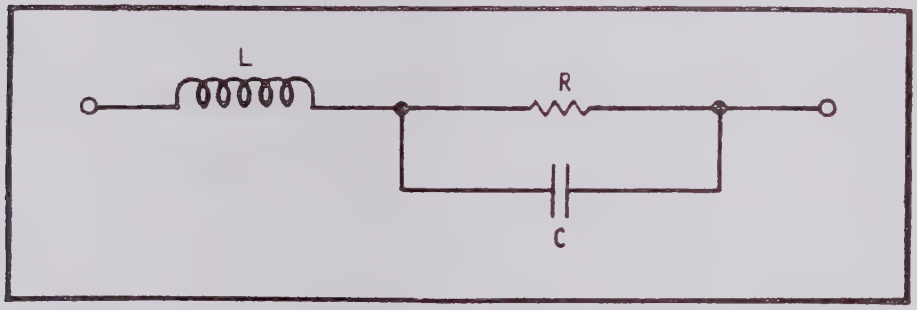
C = 50 R_{ref}/R nanofarads
(R is in ohms)
(R_{ref} is the full-scale value in ohms)

3.7 SLOW-MODE AND FAST-MODE (2724A WITHOUT CPR)

When Slow-mode is selected (adjacent LED on) the unit operates as a high-precision DC resistor with an equivalent circuit shown in Figure 3-1. In this mode the unit requires a stable DC current for correct operation.

When Fast-mode is selected (adjacent LED on) the unit operates as a medium-precision DC/AC resistor with an equivalent circuit shown below:

Figure 3-2. Fast-mode Equivalent Circuit



Where R is the required value
C is given by the table below:

0 - 120 Ω	50000pF nominal
0.12 - 1.2K Ω	5000pF nominal
1.2 - 12KΩ	500pF nominal
12 - 120KΩ	60pF nominal
0.12 - 1.2M Ω	50pF nominal
1.2 - 12M Ω	50pF nominal
12 - 120M Ω	1000pF nominal
0.12 - 1.2GΩ	1000pF nominal
1.2 - 11G Ω	1000pF nominal

L is $\pm$ 30 R_{ref} nH max . (R_{ref} in ohms)

When measured using a two-terminal hook-up the capacitor "C" above appears in series with 10KΩ.

3.8 TWO-WIRE KEY (2724A WITH CPR)

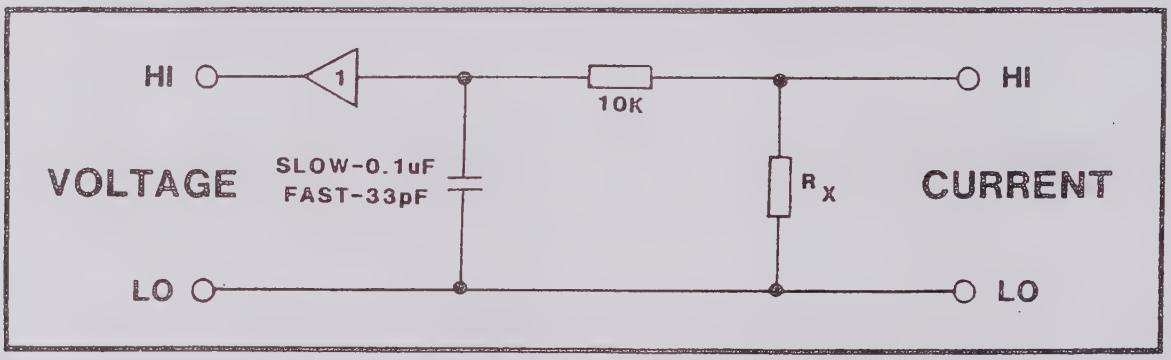
This key alternately selects TWO WIRE and FOUR WIRE modes of operation. The adjacent LED is on whenever TWO WIRE is selected, and the units' output is adjusted to compensate for

the two-terminal zero error entered during calibration (in ACTIVE mode) or the displayed value is adjusted to include the two-terminal zero error (in CPR mode).

3.9 FAST-MODE KEY (2724A WITH CPR)

This key alternately selects FAST and SLOW modes. The adjacent LED is on while in FAST-mode. All of the information regarding the equivalent circuit in the 2724A (3.7 above) is applicable when in ACTIVE mode. In CPR mode, the equivalent circuit is as shown below:

Figure 3-3. CPR Mode Equivalent Circuit



3.10 CARD PNT KEY

This key alternately selects CPR and ACTIVE modes of operation. Whilst in CPR mode the adjacent LED is on.

In ACTIVE mode the unit is just as 2724A (except the maximum current is 15mA).

In CARD PNT mode (CPR) the unit selects the cardinal point value for the "range" in which the entered value falls, (e.g. 8K will call up for 10KΩ, ØΩ will call up for 100Ω) up to a maximum value of 10M . When in CPR mode the Step Control function is disabled, the displayed value being the calibrated value of the resistor (modified for two-terminal zero offset if required).

3.11 PPM DEV KEY

This key selects for the next entered value to be compared with the currently displayed CPR Value and the deviation (in parts per million) to be displayed for 4 seconds. This key is only functional in CPR mode, and the adjacent LED is on whilst the unit is awaiting the entered value. Whilst the LED is on, this condition may be cleared by pressing "PPM DEV", or exiting CPR mode using the "CARD PNT" key.

The user should note that the maximum displayable error is +200000/-1999999 ppm.

SECTION IV - IEEE-488 INTERFACE OPERATION

4.1 IEEE-488, AN EXPLANATION OF THE BUS

The reader that is not familiar with the requirements of IEEE Standard 488 (1981) (IEEE-488) will want to review the following paragraphs which provide explanations of terms, commands and some examples of commands. For a complete explanation of the requirements, refer to the IEEE-488 Standard.

4.2 DEFINITIONS

The following are definitions of the terms used in describing the IEEE-488 interface.

Bi-Directional Bus: A 'highway' used for two-way communication, both input and output data being conveyed on the same lines.

Bus: A data link which is usually a set of several parallel wires within a multi-wire cable.

Bit Parallel: Used to describe data which is present simultaneously on a number of wires in a bus.

Byte: A group of data bits (usually 8) which are treated as a single item of data.

Byte Serial: Information, in bit-parallel bytes, transferred sequentially between devices.

Device Dependent Message: A message containing commands/data specifically for the recipient device.

Handshake: A sequence of signals, controlling the transfer of data over a bus. Each condition, in turn, must occur before the next.

Interface: The part of an instrument or system which enables it to be connected to another via a bus.

Interface Message: A message intended for interface management.

Local Operation: Operation of a device by its front panel controls (also referred to as Manual Control).

Remote Operation: Operation of device under the control of another via a bus.

The IEEE-488 Interfacing Standard (also known as IEC D'TC66-(WG3), ANSI MC1-1, GP-IB, HP-IB, etc.) defines a bi-directional bus for interconnecting programmable instrumentation in a bit-parallel, byte serial fashion. It defines limitations as follows:

A maximum of 15 devices may be interconnected by a single bus.

The total bus length may not exceed 20 meters, or the number of devices multiplied by two, whichever is the shorter.

Maximum transmission rate is 1 megabyte per second.

All bus data is digital.

Of the devices on the bus, only one may be a controller, exercising control over all other devices and also capable of operating as a "talker" or "listener". The other devices may be listeners (only able to receive data) or talkers (only able to transmit data) or both. (The 2724A is capable of talking and listening). The controller may address other devices and command them to listen or talk (only one may talk at any one time).

The interconnecting cable contains sixteen signal wires and eight ground returns linking devices into a complete system. The cable connectors consist of a plug/socket combination in order that "daisy-chaining" of units may be achieved. The sixteen signal wires comprise:

Eight data wires (DIO-Ø through DIO-7)

Five management wires (ATN, EOI, SRQ, IFC and REN)

Three "handshake" wires (DAV, NRFD and NADC)

It should be noted that these wires use "inverse logic". That is to say that a low level indicates the "true" (active) state and a high level indicates a "false" (non-active) state.

ATN - Asserted by the controller whenever an address or a command is present on the bus.

EOI - With ATN true, EOI indicates that the controller is polling devices. With ATN false, EOI is driven by the talker to indicate the end of data.

SRQ - Driven by any device. This indicates that a device requires attention (e.g., a fault has occurred). Normally, the controller will respond by polling to determine which device requires service.

IFC - Driven by the controller. This signal, when true, initializes the bus to a reset state.

REN - Driven by the controller. This signal, when true, enables the device to enter the remote state.

The transfer of data on the bus is controlled by the three handshake wires which are arranged to run at the speed of the slowest device on the bus. The talker first waits for all devices to be ready to accept data (checks that NRFD is false) then puts the data on the bus with DAV true. It then waits for all devices to indicate that the data has been accepted, by waiting for DAC to become true, before starting to transfer the next byte of data.

Data is sent in 8-bit bytes on the DIO wires, usually (as in the 2724A) using the ISO-7 standard ASCII characters. Table 4-1 lists each ASCII character and the bus messages applicable to each. Note that the table is divided into two main groups. The primary command group and the secondary command group. The secondary command group is not utilized in the 2724A.

The primary command group is further divided into four sub-groups as follows:

1. The addressed Command Group - applied only to addressed devices.

2. The Universal Command Group - applied to all devices.

3. The Listen Address Group - set of device listen addresses.

4. The Talk Address Group - set of device talk addresses.

Data in the above command groups is sent with ATN true. When data is sent with ATN false, then it is "device dependent".

4.3 GENERAL

All IEEE-488 device dependent activity with the 2724A takes place via input and output buffers.

Input Buffer - Incoming data is placed in the input buffer as it is received. It is not acted upon until any one of the valid input delimiters is received. Then the commands are decoded and the input buffer contents erased. Input data is held off until the previous data is decoded and actioned. Should an invalid character be found in the input buffer, then the buffer is only decoded up to the error, the rest being discarded. An SRQ can be asserted, if required, should this occur.

Table 4-1. ASCII Character Codes.

ISO BIT & DIO LINE NUMBER → 7 6 5 4 3 2 1	0		1		2		3		4		5		6		7		COLUMN / ROW
	ASCII	MSG	ASCII	MSG	ASCII	MSG	ASCII	MSG	ASCII	MSG	ASCII	MSG	ASCII	MSG	ASCII	MSG	
0 0 0 0	NUL		DLE		SP	00	0	16	@	00	P	16			p		0
0 0 0 1	SOH	GTL	DC1	LLO	!	01	1	17	A	01	Q	17	a		q		1
0 0 1 0	STX		DC2		"	02	2	18	B	02	R	18	b		r		2
0 0 1 1	ETX		DC3		#	03	3	19	C	03	S	19	c		s		3
0 1 0 0	EOT	SDC	DC4	DCL	$	04	4	20	D	04	T	20	d		t		4
0 1 0 1	ENQ	PPC[1]	NAK	PPU	%	05	5	21	E	05	U	21	e		u		5
0 1 1 0	ACK		SYN		&	06	6	22	F	06	V	22	f		v		6
0 1 1 1	BEL		ETB		'	07	7	23	G	07	W	23	g		w		7
1 0 0 0	BS	GET	CAN	SPE	(	08	8	24	H	08	X	24	h		x		8
1 0 0 1	HT	TCT	EM	SPD	)	09	9	25	I	09	Y	25	i		y		9
1 0 1 0	LF		SUB		*	10	:	26	J	10	Z	26	j		z		10
1 0 1 1	VT		ESC		+	11	;	27	K	11	[	27	k				11
1 1 0 0	FF		FS		,	12	<	28	L	12	\	28	l		|		12
1 1 0 1	CR		GS		-	13	=	29	M	13	]	29	m				13
1 1 1 0	SO		RS		.	14	>	30	N	14		30	n		~		14
1 1 1 1	SI		US		/	15	?	UNL	O	15		UNT	o		DEL		15

STANDARD ISO 7 CHARACTERS

ADDRESSED COMMAND GROUP (ACG)	UNIVERSAL COMMAND GROUP (UCG)	LISTEN ADDRESS GROUP (LAG)	TALK ADDRESS GROUP (TAG)	SECONDARY COMMAND GROUP (SCG)

PRIMARY COMMAND GROUP (PCG)

[1] Requires Secondary Command

Notes

1. Device Address messages shown in decimal
2. Message codes are

DCL	Device Clear	LLO	Local Lockout	SDC	Selected Device Clear
GET	Device Trigger	PPC	Parallel Poll Configure	SPD	Serial Poll Disable
GTL	Go to Local	PPU	Parallel Poll Unconfigure	SPE	Serial Poll Enable.

The valid input delimiters are:

CR (Carriage Return) or

EOI with the last character.

Output Buffer - With every display update (except fault messages), the output buffer is filled with the contents of the display. This data may be read by the controller any number of times.

The address of the 2724A is preset at the factory at Ø9. However, it may be changed by the user through the front panel keyboard. To enter a new address, press the IEEE/ADDR key and the CLR key to clear the original address. Then press the number keys corresponding to the new address and terminate the entry by pressing the Ω key.

At power-up, the 2724A will be in the local mode (i.e., the unit will respond to commands entered with the front panel keyboard). In order for the 2724A to enter the remote mode, the following sequence, stipulated by IEEE-488, must occur:

1. The remote enable, REN, wire on the bus must be true (pulled low).

2. The 2724A must receive its listen address.

With an HP 85 computer, this is achieved by the statement REMOTE 7Ø9, assuming that the 2724A address is Ø9. In all future examples, an HP 85 computer is assumed as is the 2724A address of Ø9.

When the 2724A is in remote, the REMOTE IEEE-488 indicator on the front panel will be illuminated and all front panel keys (except POWER and MAN) are inhibited. The MAN key, if pressed, will return control to the front panel. If the MAN control is also to be inhibited, then LOCAL LOCKOUT must be sent over the bus. This is achieved with the HP 85 by LOCAL LOCKOUT 7.

The computer may reset the 2724A to the local state at any time by the command LOCAL 7 (or LOCAL 7Ø9 if only the 2724A is to be returned to the local mode). Note also, that a device clear command will return the unit to local control.

4.4 SIMPLE COMMANDS AND EXAMPLES

Six simple commands, with examples, are shown in the following paragraphs.

1. **Setting a Resistance Value** -- To set the 2724A to a numeric resistance value, all that is required is to send the resistance value in ohms. Any form of the number is accepted (exponent, etc.) with a maximum of seven digits.

Digits in excess of seven are ignored. The data will not be processed until terminated or until an exponent character is received.

The delimiter for the exponent may be an ASCII "E" or "e". The overall delimiter is any invalid character within numeric entry.

The following is an example of such a program using the HP 85:

```
1Ø REMOTE 7Ø9
2Ø INPUT A
3Ø OUTPUT 7Ø9 ; A
4Ø GOTO 2Ø
```

This program will prompt a user input of value on the HP 85 and send this value to the 2724A. (It is assumed that the 2724A was just powered-up and the calibrate switch was off).

2. **Step Control** -- To utilize the 2724A's step control facility via the IEEE-488 bus, the user enters the same data as he would from the front panel. The front panel keys are replaced by the following commands:

   DON - Turns step control mode on
   DOFF - Turns step control off

   (Note use of separate commands)

   U - Same as UP arrow
   D - Same as DOWN arrow
   L - Same as LEFT arrow
   R - Same as RIGHT arrow

   See subsection 3.4 for details.

Following is an example of a program of step control using the HP 85:

```
1Ø REMOTE 7Ø9
2Ø OUTPUT 7Ø9 ; "DONLLUURDDOFF"
```

This program will cause the second from the least significant digit to be incremented twice and the next to least significant digit to be decremented. The last part of the program turns the step control mode off.

3. **Reset** -- The 2724A may be reset by either of two methods. First, an IEEE-488 Device Clear will reset the 2724A. Second, the 2724A has a device dependent command A which will produce a reset. This is of particular value when using a controller that does not have a Device Clear capability (such as the Commodore PET).

4. **CPR/Active Mode Selection (Option CPR Only)** -- To select one of these modes the user sends one of the following commands -

CØ - Selects Active Mode (power-up condition)
or C1 - Selects CPR mode.

Example: OUTPUT7Ø9 ; "C1" - Select CPR mode

5. **Two/Four-Wire Selection** -- To select either two- or four-wire correction the user sends one of the following commands -

TØ - Selects four-wire (power-up condition)
or T1 - Selects two-wire

Example: OUTPUT7Ø9 ; "T1" - selects two-wire

6. **Fast/Slow Mode Selection** -- To select either slow- or fast-mode operation the user sends one of the following commands -

MØ - Selects slow-mode (power-up condition)
or M1 - Selects fast-mode

Example: OUTPUT7Ø9 ; "MØ" - Selects slow-mode

4.5 ADVANCED COMMANDS AND EXAMPLES

One advanced command and example of execution is contained in the following paragraphs.

1. **Output Delimiters** - As mentioned earlier, the 2724A updates its output buffer with the display data. The format of this data is as follows:

"nnnnnn KOHMS QnEnPnMnTnfcou" (2724A)
or
"nnnnnn KOHMS QnEnPnMnTnCnfcou" (CPR)

followed by the required output delimiter where:

n is the required number (e.g., En returns the present output delimiter select code)

f is a space if not in step control mode, F if it is.

c is a space if not in calibration mode, C if it is.

o is a space if not in overcurrent, O if it is.

u is a space if not in undercurrent, U if it is.

The required output delimiter is set by sending an "E" followed by the required code (see controller manual for details regarding the required delimiter). The list of available codes is given below:

EØ - Carriage return line feed at end of data

E1 - Carriage return (line feed with EOI asserted) at end of data

E2 - Carriage return only at end of data

E3 - Carriage return (with EOI asserted) at end of data

E4 - EOI asserted with last character

Note that most controllers use EØ. However, the Commodore PET should use E3.

Example - If the 2724A was outputting 1Ø.ØØØ12M Ohms and was in step control mode and in undercurrent:

```
1Ø REMOTE 7Ø9
2Ø DIM A$[1ØØ]
3Ø ENTER 7Ø9 ; A$
4Ø PRINT A$
```

The resultant print-out would be:

"1Ø.ØØØ12 MOHMS QØEØPØMØT1 U"

4.6 SRQ, SERIAL POLL AND PARALLEL POLL

1. **Parallel Poll Response** -- The 2724A may have its parallel poll response bit set by means of the "P" command. The user must send "Pn" to the unit in order to configure the response, where "n" defines the DIO line that is to be asserted by the 2724A. Sending "PØ" selects that no response shall be made to a parallel poll.

2. **SRQ Definition** -- The 2724A may assert the SRQ wire for one of several reasons. This is defined by the user sending "Qn", where n is the numeric code for the required reasons.

   QØ - Disables the 2724A from asserting SRQ
   Q1 - Enables the 2724A to assert SRQ on internal errors, i.e., any displayed fault, overcurrent, undercurrent, unsettled, etc.
   Q2 - Enable to assert SRQ on input data errors, e.g., if "B" is received on the data bus (an un-decodable command)
   Q3 - Enable to assert SRQ on all reasons given in Q1 and Q2.

Q4 - Enable to assert SRQ when settled to a new value.
Q5 - Enable to assert SRQ on all reasons given in Q1 and Q4.
Q6 - Enable to assert SRQ on all reasons given in Q2 and Q4.
Q7 - Enable to assert SRQ on all reasons.

3. **Serial Poll Response Byte** -- When the controller in the system conducts a serial poll, the 2724A responds with a byte of data informing the controller of the reason for the SRQ. If the 2724A did not generate the SRQ, then a zero byte is used as the response. The bit patterns used by the 2724A are listed in Table 4-2.

Table 4-2. SRQ Bit Patterns.

REASON	BIT PATTERN IN RESPONSE
Clock Fault	0100 0001
Math Overflow	0100 0010
Bad Calibration Data	0100 0011
Bad Memory Data	0100 0100
Settled	0101 0000
Calibration Data Out of Limits	0101 0001
Unsettled	0101 0010
Out of Control	0101 0100
Undercurrent	0101 0100
Overcurrent	0101 0101
Error in Input Data	0101 0110

Note that the most significant bit is set if the 2724A is in REMOTE.

SECTION V - THEORY OF OPERATION

5.1 GENERAL

The information is this section, combined with that in sections VI and IX is all that is required to perform successful maintenance and calibration of the 2724A. Should further information be required then the user is referred to his nearest Valhalla Service Center for advice.

This section of the manual describes the operation of the 2724A. The functional description of 5.2 is intended to assist the user in gaining a general understanding of the principals behind the operation of the 2724A referring to the block diagram shown in Figure 5-1. Following this functional description in 5.3 are detailed descriptions of each circuit block referring to the schematic diagrams in section IX. These circuit descriptions are intended to provide the user with sufficient information on circuit operation to permit efficient troubleshooting.

5.2 FUNCTIONAL DESCRIPTION

The "active ohm" technique used in the 2724A is a unique analog circuit providing stability and high accuracy for a wide range of values and conditions.

Referring to the block diagram in Figure 5-1, the current (I) from the measuring device flows into the I HI terminal of the 2724A, through the reference resistor (Rref), into the internal ØV of the 2724A returning via the power rails from the output of the variable gain amplifier to the I LO terminal. Thus, the voltage across the reference resistor is I*Rref (and thus the voltage at the V HI and I HI terminals).

With the variable gain amplifier at a gain of K (Ø<K<1) the voltage at the I LO terminal (and thus the V LO terminal) is K*I*Rref. Therefore, it can be seen that the voltage between the V HI and LO terminals is given by I*Rref*(1-K), thus simulating a resistor of value Rref*(1-K). The digital circuitry in the 2724A is present to control I/O operations, set the required Rref and K, and to check the exact value of K (correcting any errors present) by utilizing the A-to-D convertor.

5.3 DETAILED CIRCUIT DESCRIPTIONS

5.3.1 REFERENCE RESISTORS

The resistors R121, 122, 123, 124, 125 and 126 are the reference resistors used in 2724A. As can be seen in schematic

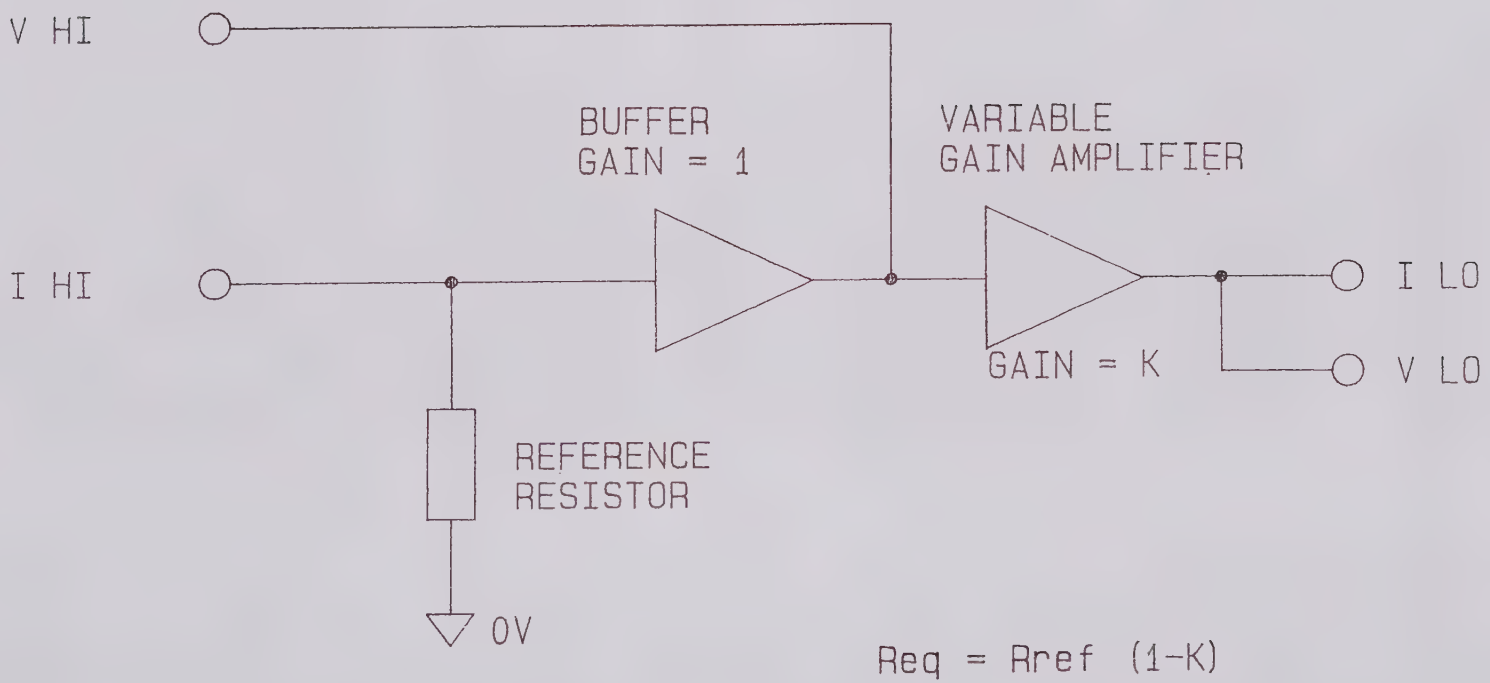


FIGURE 5-1 ACTIVE OHM BLOCK DIAGRAM

2724-ØZØ sheet 1, the actual reference resistor in use is selected by the relays RLA, B, C, D, E and F the actual selections are shown below:-

VALUE	RLA	RLB	RLC	RLD	RLE	RLF	REFERENCE RESISTOR
Ø to 12Ø ohm	Off	On	Off	Off	On	On	R124 (1ØØohm)
Ø.12 to 1.2 Kohm	Off	On	Off	On	Off	Off	R 1 2 4 + 1 2 3 (1Kohm)
1.2 to 12 Kohm	Off	On	On	Off	Off	Off	R124+123+122 (1ØKohm)
12 to 12Ø Kohm	On	On	Off	Off	Off	Off	R124+123+122+ 121 (1ØØKohm)
Ø.12 to 1.2 Mohm	Off	Off	Off	Off	On	On	R126 (1Mohm)
1.2 to 12 Mohm	Off	Off	Off	Off	Off	Off	R 1 2 6 + 1 2 5 (1ØMohm)
12 to 11ØØØMohm	Off	Off	*	*	Off	Off	R126+125 (1ØMohm)

* See 5.3.2.2 for action of RLC and D above 12Mohm.

5.3.2 REF BUFFER

5.3.2.1 Unit Gain Buffer

The unity gain buffer is formed by the amplifier IC101, powered by rails (+ and - 5 volts) that follow the input as formed by IC104, 105 and 106.

IC104 simply buffers the voltage developed across the reference resistor and forces the +5V (from IC105) and -5V (from IC106) rails for IC101 to follow this voltage. This amplifier's output is also used to detect the overcurrent situation by means of D103, 104 conducting when the voltage exceeds 13.7V, thus turning on the LED part of the opto-isolator IC411 (informing the MPU of the overcurrent).

IC101 is also connected as a unity gain, non-inverting buffer, driving the V HI terminal, reference resistor section guarding and also the variable gain amplifier (for values below 12Mohm). The input offset and input leakage current of this section are corrected for by the adjustment of RV103 and 102 respectively.

At the input to this section is a selectable filter formed by RLL, C112 and C111. This filter is selected by the Slow or Fast mode of the 2724A as defined by the user. In slow mode RLL is on, thus using C111 as the filter, whereas in fast mode RLL is off, thus using C112 as the filter.

At the output of this section is an adjustment (switched on by RLG when the Ohms Multiplier is not in use) RV101 which is used to compensate for thermal emfs on RLG and R101.

5.3.2.2 Ohms Multiplier

In order to avoid the necessity of reference resistors above 10Mohm, the effective value of the reference resistor is multiplied by 10, 100 or 1000 by the Ohms Multiplier. This is formed by the amplifier comprised of IC102 and 103, the feedback resistor network R114 and the relays RLG, H and J.

For values below 12Mohm this circuit is bypassed by RLG being off. For values between 12 and 120Mohm this amplifier is set to a gain of 10 by RLG being on, RLH being on and RLJ being off. Note that RLH and RLC are driven together as are RLJ and RLD. For values between 120 and 1200Mohm this amplifier is set to a gain of 100 by RLG being on, RLH being off and RLJ being on. For values between 1200 and 11000Mohm this amplifier is set to a gain of 1000 by RLG being on, RLH being off and RLJ being off.

The amplifier formed by IC102 and 103 is a two-stage amplifier providing the offset voltage characteristics of IC103 combined with the output swing capability of IC102.

The output of IC102 is also used to detect overcurrent by means of D101 and D102 conducting when the output exceeds 13.7V thus turning on the LED portion of IC411 in a similar manner to that described in 5.3.2.1 above.

5.3.3 VARIABLE GAIN AMPLIFIER

This section provides a variable gain from Ø to unity. It comprises of two sections:-

5.3.3.1 MDAC's

There are two virtually identical MDACs (Multiplying D to A Convertor) in the 2724A. These are formed by IC201 and 202 (Most Significant DAC) and IC203 and 204 (Least Significant DAC). The only difference between these is the accuracy of the DAC device used.

Each MDAC is a 12-bit (i.e. 1 in 4096 resolution) device using the output of the REF BUFFER as its reference voltage input. The output of each MDAC is buffered and converted into a voltage by IC202 or 204. The gain of each MDAC is adjusted by the digital codes present on the inputs D1 (Least significant) to D12 (Most significant), if this is considered as a number K (between Ø and 4Ø95) then the output of IC202 (or 204) is given by K*Vref/4096 (where Vref) is the voltage on the reference input).

The MDACs are powered by an 8V rail provided from the +18V rail by IC206.

5.3.3.2 Output Buffer

The output buffer is an inverting buffer summing the outputs of the two MDAC's with a 1ØØØ:1 weighting as defined by R202:R201.

When the input current is less than 1ØmA (approximately) then the amplifier IC205 is used directly to drive the V LO and I LO terminals, otherwise a high-power buffer amplifier IC207 is inserted into the output of IC205 to sink (or source) the required current.

The output of the Output Buffer is protected by the two 15V zener diodes D203 and 204.

If the 2724A has OPTION CPR fitted then IC207 is deleted and the NO (Normally Open) contact of RLK is directly taken to Øv. RLK is now used to select CPR mode of operation, shorting V LO and I LO to Øv, thus the output value is that of the selected reference resistor. With RLK off the 2724A operates normally, however it may only provide 15mA of current.

The actual output of the Variable Gain Amplifier is monitored by the A-to-D convertor through R210 (filtered by C203) in order to monitor the actual gain.

Under overcurrent condition the MPU pulses TR201 on to force the output to a high voltage in order to ensure that auto-ranging DVM's which require 2ØV (or more) to up-range will do so.

5.3.4 A/D CONVERTOR

The A/D convertor is shown on schematic 2724-070 sheet 3 and comprises four sections:-

5.3.4.1 Pre-Scaling and Input Multiplexing

The input to the A-to-D convertor is selected from one of three sources (Zero, REF BUFFER output, V LO terminal) by the analog multiplexer IC301. This signal is pre-scaled to within 4-13V by the amplifier IC302, gain defining resistors R301-308 and multiplexer IC303.

Control of both multiplexers is by the MPU under software control, the input being multiplexed in order to calculate the ratio between the output of the REF BUFFER and the voltage on the V LO terminal, eliminating zero errors.

5.3.4.2 Reference Voltage Generator

The reference voltage for the A-to-D convertor is generated by IC307 at 6.95V (nominally). The A/D convertor requires both positive and negative reference voltages thus the reference is inverted by amplifier IC308 to produce the required negative voltage. RLM selects the polarity used by the A/D convertor to operate for the polarity of input current to the 2724A.

5.3.4.3 FET Switch Drives

The A/D convertor requires two high-speed FET switch drivers. These are both essentially identical and are comprised of IC309 in combination with TR303, R319-321 and C304 (TR302 drive) or TR304, R326-328 and C305 (TR301 drive). These drivers take the TTL level signal (REF DRIVE) which is referred to the -18V rail, and provides the wide voltage swing required to switch the FETs TR301 and 302.

5.3.4.4 Current Balance

The currents formed through R309 (from the input), R317 (from the reference) and R318 (from the FET switches) are summed in the integrator IC304 and C302. Any imbalance in these currents will cause the output of IC304 to move thus causing the comparator IC305 to switch. The output of this comparator is synchronized to clock and fed back to drive the REF DRIVE line, thus causing the current through R318 to be altered. The 667Hz input to the A/D convertor through C301 and R310 forces the convertor to operate continuously at a frequency which is independent of the input. This synchronization is performed in the MPU section described in section 5.3.5.1.

Under normal operating conditions the output of IC304 will be a distorted triangle wave and the output of IC305 will be a TTL level square wave with a duty cycle proportional to the input voltage at that time. The waveform at the junction of TR301, TR302 and R318 will also be a square wave with levels of ØV and Vref (Vref will be -6.95V with a positive input, +6.95V with a negative input).

5.3.5 FLOATING SECTION ISOLATION

All of the section described above are floating, being driven to the common-mode voltage of the measuring device. All of the I/O and MPU circuitry in the 2724A are grounded thus isolation is required between these two parts of the 2724A. This is achieved by the circuitry shown in schematic 2724-070 sheet 4. The circuitry used is basically simple employing opto-isolators IC's 401 to 413 to isolate all of the signals passing between the two parts. IC414 and TR's 403 to 406 are used to drive the relays from the outputs of the opto-isolators. TR401 is used to drive the 667Hz drive to the A/D convertor. TR402 is used to drive TR201 in the Variable Gain Amplifier. The various

discrete and film-network resistors being used for current definition in the LED's in the opto-isolators and as pull-ups for the opto-isolator transistor outputs.

5.3.6 MICROPROCESSOR

The microprocessor section of the 2724A is shown in schematic 2724-070 sheet 5 and is in five sections:-

5.3.6.1 A/D Convertor Logic

The logic for synchronization of the current balance output to the main clock and the accumulation of A/D convertor measurements is performed by ICs 501 to 509 in combination with the MPU under software control. The opto-isolated output of the current balance is first passed through an exclusive OR gate in IC503 which is used to invert or non-invert this signal dependent on the polarity of input current (and thus reference used in the A/D convertor), this signal is now synchronized with the 12.8MHz clock and de-bounced by ICs 501, 502 and parts of ICs 503 and 504. The true output of the final stage (IC502) is used as the REF DRIVE signal for the FET switch drivers in the A/D convertor (after isolation) and the untrue output is gated with the clock to generate a count signal for the 16-bit counter formed by IC506 and 507. Due to the already described operation of the A/D convertor this signal will be a group of clock pulses every 1.333 milliseconds, with the number of pulses being proportional to the input voltage to the A/D convertor at that time. IC505 is used to produce a pair of pulses immediately following each of these groups of pulses, the first pulse is used to latch the count in the 16-bit counter into latches IC508 and 509, the second being used to clear the 16-bit counter to zero ready for the next group of pulses. Thus, at 667Hz, the latches IC508 and 509 are updated with the latest 16-bit measurement taken by the A/D convertor. The second pulse from IC505 is also used to interrupt the microprocessor, informing it that a new measurement may be read from the latches. The microprocessor then accumulates these measurements until sufficient resolution is obtained.

5.3.6.2 Opto-Isolator Latches/Drivers

The opto-isolators are driven by several latches IC514-517 and 526 with the required data. The microprocessor loads the data into these latches by simply "writing" the 8-bit data into them, each being at a defined address.

5.3.6.3 Microprocessor (MPU)

The microprocessor is a Motorola MC6809 8-bit device running from a 6.4MHz clock generated from the main 12.8MHz clock. It is beyond the scope of this manual to fully describe the operation of the 6809 and thus the user is referred to the many data sheets and books available on this device.

The connections to the microprocessor fall into four groups or busses:

1) Address Bus - This 16-bit parallel bus contains the address of the device or byte to be read from/written into. It is not used as a tri-state bus nor is the MPU ever halted, thus these bus signals should always be at the two logic levels (except during transition).

2) Data Bus - This 8-bit parallel bus contains the data read from/written to the device whose address is present on the address bus. This is a tri-state bus and various different levels will be seen on these signals.

The MOS devices on this bus are unable to drive the many TTL devices required on this bus, thus they are buffered from the MPU data bus by IC511.

3) Control Bus - This describes the two lines Ø and R.
Ø is the MPU clock and is 1/4 of the 6.4MHz clock to the MPU (i.e. 1.6MHz). All buss transactions take place at the trailing (i.e. 1 to Ø) edge of this signal.
R is the read/write control signal and is a 1 whilst the MPU is reading data and is a Ø whilst writting. Neither of these two signals are tri-state and thus are always at one of the two logic levels.

4) Interrupts - There are four interrupts used in the 2724A.

RESET - This line is normally pulled to +5V by R503, but is held low for approximately 300mS (by C503) after applying power to the 2724A. This action causes initialization of the MPU and restarts the software.

NMI - This line is normally at a logic 1, going to a Ø when a new measurement is available from the A/D convertor.

FIRQ - This line is normally at a logic 1 and is driven from the display drive circuitry to indicate that the next position in the display is to be updated.

IRQ - This line is normally at +5V, being pulled-up by R504. It is used by the IEEE-488 interface to indicate that an IEEE bus action has taken place.

5.3.6.4 Address Decode

The decoder IC's 524 and 525 perform the decoding of the address bus into the individual addresses of the various devices connected to the data bus. Only the lines A9 to 15 are used and the decode is synchronized to the MPU clock by IC708.

5.3.6.5 Memory

The memory in the 2724A comprises ROM (IC519 - 8kx8 UVEROM), static RAM (IC's 520 and 521 - 1kx4 each, organized as 1kx8) and non-volatile RAM (IC's 522 and 523 - 256x4 each, organized as 256x8). Each of these has its address range decoded by IC524. The non-volatile memory also has address decode for addresses controlling the reading and writting of the NOVRAM portions of these memories. IC522 is used to hold the calibration data for the 2724A and thus has its write control switched by the key switch whilst IC523 is used to hold the user memory data and thus does not.

5.3.7 CLOCK, DISPLAY AND KEYBOARD

IC527 and Y501 form the 12.8007 MHz oscillator for the main system clock. This clock is then divided down in sequence by IC528 (giving 128KHz), IC529 (giving 667Hz). These components are shown on schematic 2724-070 sheet 6.

The display is a 16-digit 14-segment vacuum fluorescent type, multiplexed at 2.66KHz by the main system clock. The display itself is mounted on the Display PCB behind the front-panel and is shown on schematic 2724-071. The grid of each decade is pulled up by ICs 703 and 704 to +37V one at a time, as defined by decoder IC705 and inverters IC706 and 707. Each time that a new decade is turned on the latch IC532 is set by the clock thus blanking the display and interrupting the MPU. The MPU responds by writting the new data for that decade into latches IC512 and 513, driving the drivers IC701 and 702 with the new data for each individual segment of the new display decade. The MPU then clears the latch IC532 enabling the display again. The front-panel LEDs DS702-708 are driven by the spare output of the 16-bit latch driving the segments of the display, buffered by TR701. The actual position of the decade in the display is synchronized by the last decade drive being fed-back into the MPU via buffer IC510.

The keyboard formed by the front-panel switches shown on schematic 2724-071 are also multiplexed along with the display. Each decade of the display causes a group of four switches to

be enabled. The MPU reads the switches by reading the buffer IC510.

5.3.8 IEEE-488 INTERFACE

This option comprises a PCB mounted on the rear-panel of the 2724A. The circuitry contained on this PCB is shown on schematic 2724-072.

ICs 3 and 4 buffer the actual IEEE bus lines from the IEEE interface IC2, which is buffered from the MPU data bus by IC1.

An exact description of the operation of the IEEE-488 bus and that of the IEEE interface IC2 are beyond the scope of this manual and the user is referred to the IEEE-488 (1981) standard and the Motorola documentation on the MC68488 chip.

5.3.9 POWER SUPPLIES

The circuitry providing the various power rails for the 2724A is shown on schematic 2724-070 sheet 7. This contains the transformer T1 whose outputs are rectified by D601-606, filtered by C601, 602, 604-607, regulated by ICs 601 to 606.

SECTION VI - CALIBRATION AND MAINTENANCE

6.1 A BRIEF DISCUSSION OF THE CALIBRATION PROCEDURE

The calibration of the 2724A is done using a current source, a standard resistor and a voltmeter. With the switch box you can switch the voltmeter and the current source back and forth between the 2724A and the standard resistor. Using ohms law (R*I=E) you can tell what the voltage would be. For example 100 ohms at 10 milli Amps = 1 volt. When the 2724A asks you for 100 ohms at 10 milli Amps you need to put in exactly 10 milli Amps. The way to obtain exactly 10 milli Amps is to refer to the standard resistor.

Switch the switch box to the standard resistor. Now, using ohms law, the value of the standard resistor is 99.9985 ohms, the current 10 milli Amps, so the voltage would be 0.999985 volts. If the voltmeter does not read that voltage, then adjust the current source until it does. When you have it adjusted, switch the switch box back to the 2724A. You should read 1.00000 volts on the voltmeter. If you don't, then adjust the 2724A using step control until you do. Switch back to the standard resistor you should read the value of the resistor 0.999985, switch back to the 2724A you should read the value of 2724A 100 ohms 1.00000 volts.

Most of the cal steps are done this way, however, there are a few that require more explanation. 0 ohms at 10 milli Amps gain ohms law 0*10 milli Amps=0.00000 volts. If it's not 0 volts, but a negative voltage you can use the step control to step it up to 0 volts. If the voltage is positive you have to enter in the value on the 2724A key board. Let's say the voltage was 0.00543 volts using ohms law that would be 0.543 ohms. So type .543 and hit the ohm key on the 2724A. The 0 ohms at 10 milli Amps will appear twice. The second time you see it, make sure you move the voltage sense lead over to the I terminals, so both leads are coming off the I terminals. This is a two wire 0 ohm calibration. After this calibration point, make sure you move your voltage sense leads back to the V terminals.

The next step of concern is when it asks you to apply 10 milli Amps you must apply 10 milli Amps. It will ask you twice. Watch the voltmeter. The first time it will be around 0 volts. The next time it will be around 10 volts. If your unit is a CPR 2724A then it will ask you to calibrate the internal resistors in the 2724A 100 ohms, 1K ohm, 10K ohms, 100K ohms, 1M ohm, and 10M ohms. For each of these cardinal point resistors you will use the switch box, the current source, the standard resistor, and the voltmeter in the same way you did before except instead of adjusting the 2724A with the step control for 1.000000 volts, you need to enter in the value. For instance CAL 100 ohm CPR, you use the switch box switch to your standard resistor and set your

current to 10 milli Amps. Now switch to the 2724A, say the voltmeter reeds 1.000056 volts, you would enter on the 2724A keyboard 100.0056 and hit the ohms button.

You use this same procedure for all the other cardinal point resistors. Make sure you hit the ohm key when it asks for ohms, the K ohm key when it asks for K ohms, and the M ohm key when it asks for M ohms. Any cal step can be skipped except apply 10 milli amps. If you are going to skip steps remove any current input while skipping, except when it asks you to apply 10 milli Amps do so. When skipping over CPR cal make sure you press ohm for ohm, K ohm for K ohm, and M ohm for M ohm. If all goes well the 2724A will say Fast Data OK , Cal Data OK , Turn Cal Switch Off.

6.2 GENERAL

This section provides calibration procedures using the front panel controls or the IEEE-488 bus. A troubleshooting chart is also provided which lists a number of trouble symptoms and the components or circuit areas which may produce them. It should be noted that a Calibration Kit (Option M-24) containing a switch assembly, cables and miscellaneous items is available from Valhalla.

6.3 CALIBRATION

It is recommended that calibration be performed with the 2724A fully assembled (i.e., with covers in place) and after power has been applied for a minimum of one hour to achieve temperature stabilization. Calibration may be accomplished manually, using the front panel controls, or automatically through the IEEE-488 interface. In all cases ACTIVE mode is used unless otherwise stated.

6.3.1 STEP 1 (NON-CPR UNITS)

The following procedure should be followed prior to full calibrations:

a) With a DVM with 1 micro Volt sensitivity monitor the voltage between V LO and V HI terminals. Disconnect any connections to the I terminals and select 100 ohms on the front panel. Adjust RV201 for A DVM reading of 0 +/- 30 micro Volts.

6.3.2 STEP 2 (NON-CPR UNITS)

These adjustments are required only if a component has been changed - periodic adjustment is unnecessary.

a) Ensure there are no connections to either front or rear terminal sets.

With a DVM with 1 micro Volt sensitivity monitor the voltage between the rear end of R126 and the rear end of R106 (use copper alligator clips).

Select SLOW-MODE AND FOUR-WIRE

Setting	DVM Reading	Adjust
0 ohm	0 ± 2 micro Volt	RV103
10 M ohm	0 ± 20 micro Volt	RV102

Repeat until no further adjustment is required.

b) Monitor the voltage between the rear end of R126 and the ground-plane near IC301. Adjust RV301 for a DVM reading of 0 ± 2 micro Volts.

c) Connect a current source to the "I" terminals and monitor the "V" terminals with the DVM.

Select 0 ohms Adjust RV101 such that the DVM reading at 500 micro Amps is 1/20th of that at 10mA.

2724A - Select 100 ohm Adjust RV103 such that the DVM reading at 500 micro Amps is 1/20th of that at 10mA.

2724A/CPR - Select CPR mode. Adjust RV103 such that the DVM reading at zero current is 0 ± 1 micro Volt.

6.3.3 2724CPR ADJUSTMENT PROCEDURE

This procedure replaces that contained in paragraphs 6.2.1 and 6.2.2 of the manual and concerns the procedure by which the internal adjustments in the 2724CPR are performed, the procedure for non-CPR units is unchanged. Note that all of these adjustments are recommended to be performed before each calibration of the unit. The user should note that the internal adjustments MUST BE MADE WHILE THE UNIT IS IN THERMAL EQUILIBRIUM. THUS THE TOP COVER MUST BE IN PLACE WHEN MEASUREMENTS ARE MADE. The user is recommended to use a top cover with small holes in it for the internal adjustments, this is available from Valhalla under the part number M24 (a switch box for the switching of the current source between the standard and the 2724 is also provided). If the top cover is lifted to perform the adjustment then the user

must ensure that the unit has thermally recovered before making any further measurements.

Equipment Required

a) A Digital Voltmeter with at least 1uV resolution at 1V and below, and 10uV resolution at 1 to 10V levels.

b) A current source providing 10mA, 1mA with less than 1ppm low frequency noise and better than 1V compliance capability.

STEP 1 - RV201 - ACTIVE/FAST Mode Output Voltage Offset

Monitor the voltage between the front panel V LO and V HI terminals with the DVM. Disconnect any connections from the I terminals and select 0 OHM/ACTIVE/FAST on the 2724CPR.

Adjust RV201 for a DVM reading of 0 +/- 50uV.

STEP 2 - RV103 - Current Sense Voltage Offset

Monitor the voltage between the front panel V LO and V HI terminals with the DVM. Disconnect any connections from the I terminals and select 100 OHM/CPR/SLOW on the 2724CPR.

Adjust RV103 for a DVM reading of 0 +/- 1uV.

STEP 3 - RV102 - Current Sense Current Offset

Monitor the voltage between the front panel V LO and V HI terminals with the DVM. Disconnect any connections from the I terminals and select 10 MEGOHM/CPR/SLOW on the 2724CPR.

Adjust RV102 for a DVM reading of 0 +/- 20uV.

STEP 4 - RV101 - Active Ohms Voltage Zero Offset

Monitor the voltage between the front panel V LO and V HI terminals with the DVM. Select 0 OHM/ACTIVE/SLOW from the 2724CPR. Alternately connect the source of 10mA and 1mA to the I terminals. The accuracy of the current source should be better than +/- 0.5% at each level.

Adjust RV101 such that the DVM reading at 10mA is ten times (i.e. the same resistance value) the DVM reading when 1mA is applied.

STEP 5 - RV301 - ACTIVE/CPR Alignment

Monitor the voltage between the front panel V LO and V HI terminals with the DVM.

i) Select 100 OHM/CPR/SLOW from the 2724CPR. Apply the source of 10mA current to the I terminals of the 2724CPR. Noting the DVM reading in CPR mode, select the ACTIVE mode (press the CARD PNT key). Note the change in DVM reading (in uV) between the two modes of operation (ensure sufficient time is given for the 2724CPR to settle before noting each DVM reading).

ii) Repeat the measurements taken in i) above with 1mA current instead of 10mA. Adjust RV301 such that the change in DVM reading at 1mA is 1/10th that at 10mA (within 1uV) repeating i) and ii) as required until no further adjustment is required.

All of the above steps should be repeated until no further adjustments are required. The 2724 is now ready for front panel calibration of the values. In cases where a component has been changed, or where the 2724 was found to have excessive errors in any step, then it is recommended that the entire calibration procedure be repeated.

6.3.4 FRONT PANEL CALIBRATION

This section shows the procedure required for the 2724A to "Learn" its errors, via the front panel.

The general concept behind the procedure for the 2724A is to adjust the output to be that which it should be, then ENTER this adjustment. The 2724A now remembers the amount of adjustment required and will automatically use this for all future outputs required.

It should be noted that:

a) A calibration step in 6.3.1 and 6.3.2 may be skipped by pressing either the ohm, K ohm or M ohm key without adjusting the output.

b) **THE 2724A MUST NOT HAVE POWER REMOVED WHEN THE KEY OPERATED SWITCH IS IN THE "CALIBRATE" POSITION.**

c) If errors of greater than 1% (or 10 milli ohms) are found, then the user should carefully check his calibration equipment before adjusting the 2724A.

6.3.5 STEP 3 - ACTIVE MODE CALIBRATION (all units)

A Equipment Required

1. Current Source capable of delivering 1 micro Amp to 10 milli Amp @ 10V compliance and 30mA @ 3V compliance. Current noise to be less than ± 2 ppm peak. (e.g. Valhalla 2701C +n 2500 in combination).

2. Resistance Standards of 100 ohm, 1 K ohm, 10K ohm, 100K ohm, 1M ohm and 10M ohm with values known to within 10 ppm.

3. Digital Voltmeter with at least 10 micro Volt resolution @ 10v or 3v, and 1 micro volt resolution @ 1v or below.

4. Cabling or switch box - See Figure 6-1. (Switch box is available from Valhalla under Option M-24. Cabling must be low thermal and have a leakage resistance of 10^{13} ohms.

B Calibration of the resistance values requires that the key operated switch in the rear panel of the 2724A be placed in CAL position.

C After performing step B (above) the unit will display "CAL 0 OHM/030mA (010mA if CPR option unit).

The user should apply the requested current to the I terminals. The current may be within ± 10% of the requested value.

If the unit exhibits a positive error, then the user should use step control to zero (within 1 milli ohm) the output and, staying in step control mode, press the ohm, K ohm and M ohm key. The unit will step on to D, below.

D The display will now show "CAL 100 OHM/030mA" (010mA if option CPR unit).

The user should adjust, (using a standard resistor of the same value as the 2724A, and DVM) the current source to within ± 5 ppm of the requested value. Now connect the current to the I terminals of the 2724A and monitor the V terminals with the DVM.

Adjust, using step control, the 2724A's value until the exact cardinal value is achieved. It is suggested that

the current source be rechecked as shown above, and then the 2724A reset until no further adjustment of the 2724A is required in order to obtain the required value to within ± 5 ppm.

Ensuring that the 2724A is still in step control mode, and that the current is flowing in the I terminals, press the ohm, K ohm or M ohm key. The unit will then step on to the next step.

E The display will now "CAL 1KOHM/010mA"

The user should now follow the same procedure as shown in D Above.

F The display will now show "CAL 10KOHM/1mA"

The user should now follow the procedure shown in D above.

G The display will now show "CAL 100KOHM/100µA"

The user should now follow the procedure shown in D above.

H The display will now show "CAL 1MOHM/10µA"

The user should now follow the procedure shown in D above.

I The display will now show "CAL 10MOHM/1µA"

The user should now follow the procedure shown in D above.

J The display will now show "CAL 100KOHM/1µA"

The user should now follow the procedure shown in D above, however it is only necessary to adjust the current source and 2724A to within ± 0.05% and not ± 5ppm as used in D.

K The display will now show "CAL OOHM/30mA" (10mA if CPR unit)

The user should note that the TWO WIRE LED is on during this step, and a two-wire check should be made (monitor I instead of V terminals) in a similar manner to that in step C above.

L The display will now show "APPLY 10mA" (Note: Units with early ROM's, before V-FB will display 100mA)

The user should apply the requested current (+ 10%) to the I terminals and monitor the V terminals with the DVM.

The DVM reading will settle to approximately zero.

When settled press the Ω , KΩ or MΩ key. The unit will step on to the next step.

M The display will now show "APPLY 10mA"

The same procedure as in L, above, should be followed, the DVM reading settling to 10 volts instead of zero.

6.3.6 STEP 4 - CPR CALIBRATION (Option CPR Only)

A The display will now show "CPR 100Ω/CAL"

The user should adjust (using the standard resistor of the same value as the nominal 2724A value, and the DVM) the current source to provide 30mA ± 0.3μA.

Now connect the current source to the I terminals of the 2724A and monitor the V terminals with the DVM.

The user should now enter the actual value of the 2724A - ENSURE THAT THE ENTRY IS FULLY CORRECT BEFORE PRESSING A UNITS KEY (Ω, KΩ or MΩ) AND THEN ENSURE THAT THE CORRECT UNITS ARE ENTERED.

After pressing the Ω, KΩ or MΩ key above, the unit will step on to the next step.

B The display will now show "CPR 1KΩ/CAL"

The procedure in A above should be followed with 10mA ± 5ppm current.

C The display will now show "CPR 10KΩ/CAL"

The procedure in A above should be followed with 1mA ± 5 ppm current.

D The display will now show "CPR 100KΩ/CAL"

The procedure in A above should be followed with 100μA ± 5ppm current.

E The display will now show "CPR 1MΩ/CAL"

The procedure in A above should be followed with 10μA ± 5ppm current.

F The display will now show "CPR 10MΩ/CAL"

The procedure in A above should be followed with 1μA ± 5 ppm current.

6.4 STEP 5 - COMPLETION OF CALIBRATION

After step 3 (2724A) or step 4 (CPR option) the unit will report on the calibration.

If step 3 L or M was not completed (insufficient current) then "NO FAST DATA" will be displayed and the FAST mode calibration data left as it was before calibration.

If both step 3 L and M were successfully completed then "FAST DATA OK" will be displayed and the FAST mode calibration data will be updated.

If any calibration data is outside the tolerance limits of the 2724A then "OUT OF CAL" is then displayed, otherwise "CAL DATA OK" is displayed.

The unit will then display "TURN CAL SW OFF". The user should now turn the rear panel key operated switch to the OPERATE position. Calibration is now completed.

6.5 AUTOMATIC CALIBRATION

The procedure for automatic calibration utilizing the IEEE-488 bus is the same as for the front panel calibration. DIGIT STEP CONTROL or direct entry methods of calibration may be used. The messages required are the normal ones used for STEP CONTROL or numeric entry. The present calibration point may be easily ascertained by simply reading the 2724A display.

6.6 TROUBLESHOOTING

It is not possible to anticipate all failure modes of the integrated circuit devices and other components of the Model 2724A. Therefore, the servicing technician should be familiar with the contents of Section V -- Theory of Operation. Knowledge of circuit operation is a requisite for efficient servicing of the 2724A. As a servicing aid, the following troubleshooting chart, Table 6-1, lists a number of fault symptoms and possible sources. If the exhibited symptom is not listed or a check of the sources listed does not locate the defective component, it will be necessary to employ normal troubleshooting procedures. In general, the list of potential error sources are in order of probability (most probable first).

Figure 6-1. Calibration connections

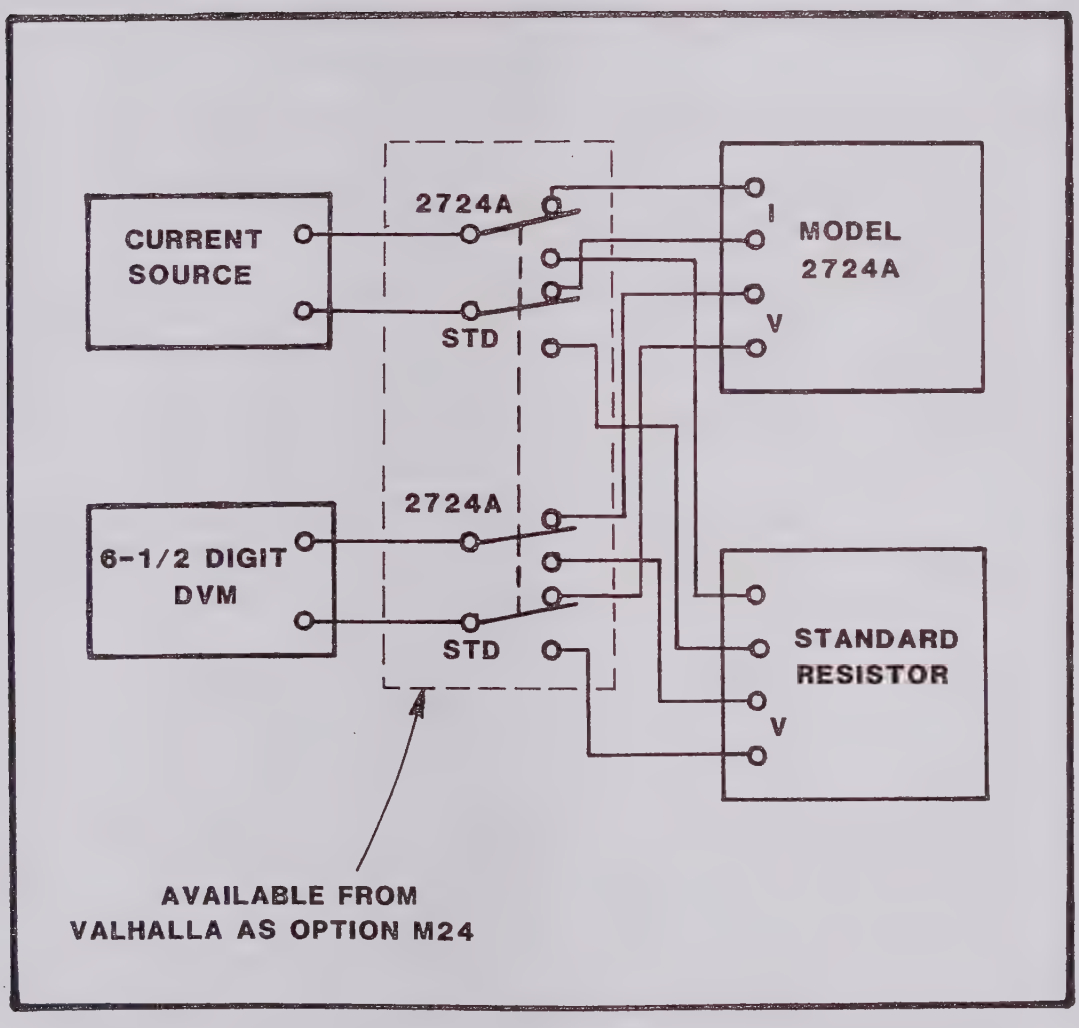


Table 6-1

Troubleshooting Guide

SYMPTOM	POSSIBLE FAULT AREA
All decimal points displayed.	MPU or ROM failure. Address Decode.
All middle segments displayed.	RAM failure.
"OUT OF CAL" displayed.	Unit mis-calibrated. Reference resistor bad. MDAC bad.
"CAL DATA BAD" displayed.	Bad NOVRAM.
"CLOCK FAILURE" displayed.	Incorrect display multiplex frequency.
"CANNOT CONTROL" displayed.	Unit mis-calibrated. MDAC bad. A/D Convertor bad.
"MEMORY DATA BAD" displayed.	If repeats after turning power off and back on, then NOVRAM bad.
"A TO D TIMEOUT" displayed.	A/D Convertor bad. Unit mis-calibrated. Unit in overcurrent, but overcurrent circuitry bad.
No display or LEDs.	Faulty line power or fuse. Power Supply bad. Clock bad. Display circuitry bad. MPU bad. Address decode bad.
Large errors, all ranges.	Check measuring equipment. A/D convertor bad. REF Buffer bad. RLB bad.
Large error, one range.	Reference resistor bad. Relay bad. Unit mis-calibrated.

Table 6-1 (Continued)

Troubleshooting Guide

SYMPTOM	POSSIBLE FAULT AREA
Error, increasing with higher value.	Excessive Leakage in relays. REF buffer bad.
Noise, all ranges.	A/D convertor bad. REF buffer bad. Check measuring equipment.
Noise, particularly on higher values.	Reverse leads to measuring equipment. REF buffer bad.
Output stuck at high (>10v) Voltage, with no input	Variable Gain Amplifier.
Value "hunts" between two or three levels.	MDAC bad.

SECTION VII - AVAILABLE OPTIONS

7.1 GENERAL

This section describes several options available from Valhalla Scientific to increase the utility of the Model 2724A.

7.2 OPTION TL-1

Option TL-1 is a Talk/Listen IEEE-488 (GPIB) Interface. It is fully described in Section IV.

7.3 OPTION RX-3

Option RX-3 provides all parts required for mounting the Model 2724A in a 19-inch equipment rack.

7.4 OPTION BBL

Option BBL is a dual shielded cable equipped with banana plugs. It is 48 inches long with dual banana plugs of the highest quality and low leakage.

7.5 OPTIONS GP1, GP2

Options GP1 and GP2 are IEEE-488 (GPIB) cables of one meter and two meters in length, respectively.

7.6 CALIBRATION KIT M24

This option contains a switch assembly, cables and miscellaneous items for aiding calibration of the Model 2724A.

7.7 OPTION CPR

This option enables the user to select the "CPR" mode of operation (see section III).

7.8 SP-2

This option provides a selection of the most probable components to fail during 24 months of operation.

SECTION VIII - USEFUL HINTS

8.1 GENERAL

This section contains a number of useful hints that will assist the user in obtaining maximum utility from the Model 2724A. As experience with the Model 2724A in the field is accumulated, this section will be expanded in later issues of this manual.

8.2 UNSTABLE TEST CURRENTS

As can be seen in the specifications, the Model 2724A requires approximately one second to respond fully to a change in test current. Thus, with ohmmeters having the facility of automatically switching polarity or to zero current (i.e., HP 3456), this facility must not be used.

With units having "uncontrollably" unstable test currents, then FAST mode or CPR mode (if fitted) should be used (e.g. Fluke 8502 series).

8.3 WHEATSTONE BRIDGE COMPARISON TO STANDARD RESISTORS

The Wheatstone bridge technique for comparing two four-terminal resistors will not operate with the Model 2724A. This is because all of the current must pass through the current (I) terminals of the unit. Thus, the lead compensation current would cause an error as shown in Figure 8-1. Using the system for comparing the Model 2724A wired as a two-terminal device presents no problems, but produces greater errors.

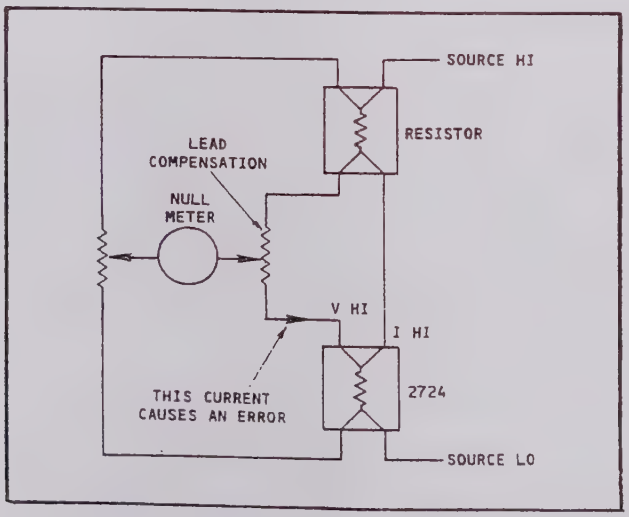


Figure 8-1. Wheatstone Bridge Error.

8.4 USE WITH HIGH RESISTANCE METERS

Several hints are provided here to help when using the Model 2724A with high resistance meters.

1. Remember that the maximum currents are:

   12ØM ohms -- 12Ø nA
   12ØØM ohms -- 12 nA
   12,ØØØM ohms -- 1.2 nA

   These correspond to 14 volts at full-scale.

2. Noise is significantly worse when used with a constant current source rather than a constant voltage.

3. Great care must be taken with regard to leakage. Regular PVC wire does not provide sufficient insulation. Teflon or polyethylene insulation should be used.

4. Care should be taken to minimize line pick-up. Outer shields of coaxial cables, LO terminals of meters, etc., MUST always be taken to low impedance nodes. If unstable indications are observed, try reversing the leads to the meter.

8.5 USE WITH ACTIVE FEEDBACK CURRENT SOURCES

Some ohmmeters utilize an active technique of ohms measurement and may not operate properly with the equivalent circuit of the 2724. In general the use of CPR mode (if fitted) or FAST mode is recommended. If this is not possible it has been found that a 0.1 µF to 1 µF capacitor (preferably Polycarbonate or Polystyrene) across the I terminals will usually prevent problems.

8.6 LINE INTERFERENCE

Some multimeters have poor line interference rejection when operated as an ohmmeter, thus care with line pick-up must be exercised. In extreme cases (e.g. when line cables run close to input cables) it may be found beneficial to place a capacitor across the I terminals to produce a 100 ms time constant. It may occasionally be beneficial to reverse the leads since some DMM's have better rejection on one terminal than the other (e.g. Guildline 9574 and Solartron 7060 should have cable shields taken to HI).

ADDITIONAL USEFUL HINTS

Rack mounting

The 2724 is sensitive to thermal gradients in the surrounding ambient, thus the user must ensure that at least 1.75" of free air is allowed around the 2724 when rack mounted. The user should also ensure that the unit immediately below and the unit above do not exhaust warm air onto the case of the 2724.

Voltage Offset Errors

Within the specification pages of this manual, values will be found for the maximum "Noise and Thermals" of the 2724. It will be noticed that only 4-wire operation is specified. The typical 2-wire thermal offsets are +/-20uV. This figure (and also the other figures quoted) will cause apparent errors on some ohmmeters. The user is recommended to ensure that the 2724 is in a thermally stable environment and that the leads between the 2724 and the meter under test are of reasonably good quality low thermal emf type in order to reduce this effect as far as possible. In severe cases the user may reverse the connections to the meter under test and take the average of the two ohmmeter readings, this will completely eliminate the thermal emf error, leaving only the effects caused by noise (typically < 1uV in CPR mode, < 3uV in ACTIVE mode).

SECTION IX - DIAGRAMS

9.1 GENERAL

The illustrations in this section are the schematic, logic and assembly diagrams of the Model 2724A. To the extent practical, an assembly diagram faces the appropriate schematic or logic diagram. All diagrams are reductions of factory engineering drawings. Title blocks, and other information not required for maintenance of the unit, have been removed.

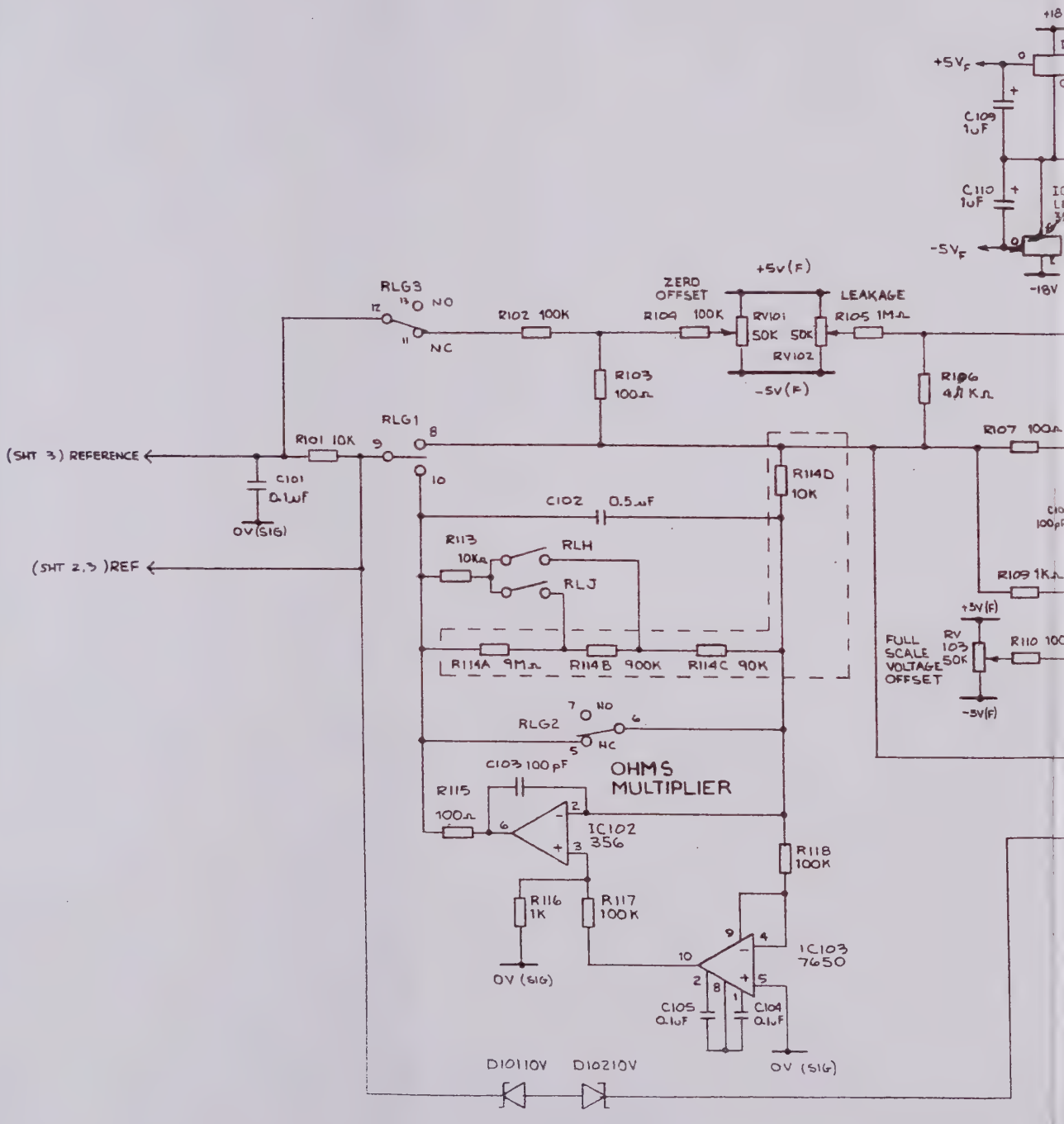
SECTION X - PARTS LISTS

10.1 GENERAL

The parts lists of this section are reproductions of factory parts lists. The designators are those of the diagrams in Section IX. When ordering replacement parts, provide the reference designator, manufacturer's part number, manufacturer's name and Valhalla part number if contained in the parts list. The manufacturer is identified in the parts list by a federal stock number. A list of manufacturer's federal stock codes is provided as an appendix to this manual for identification of manufacturer's.

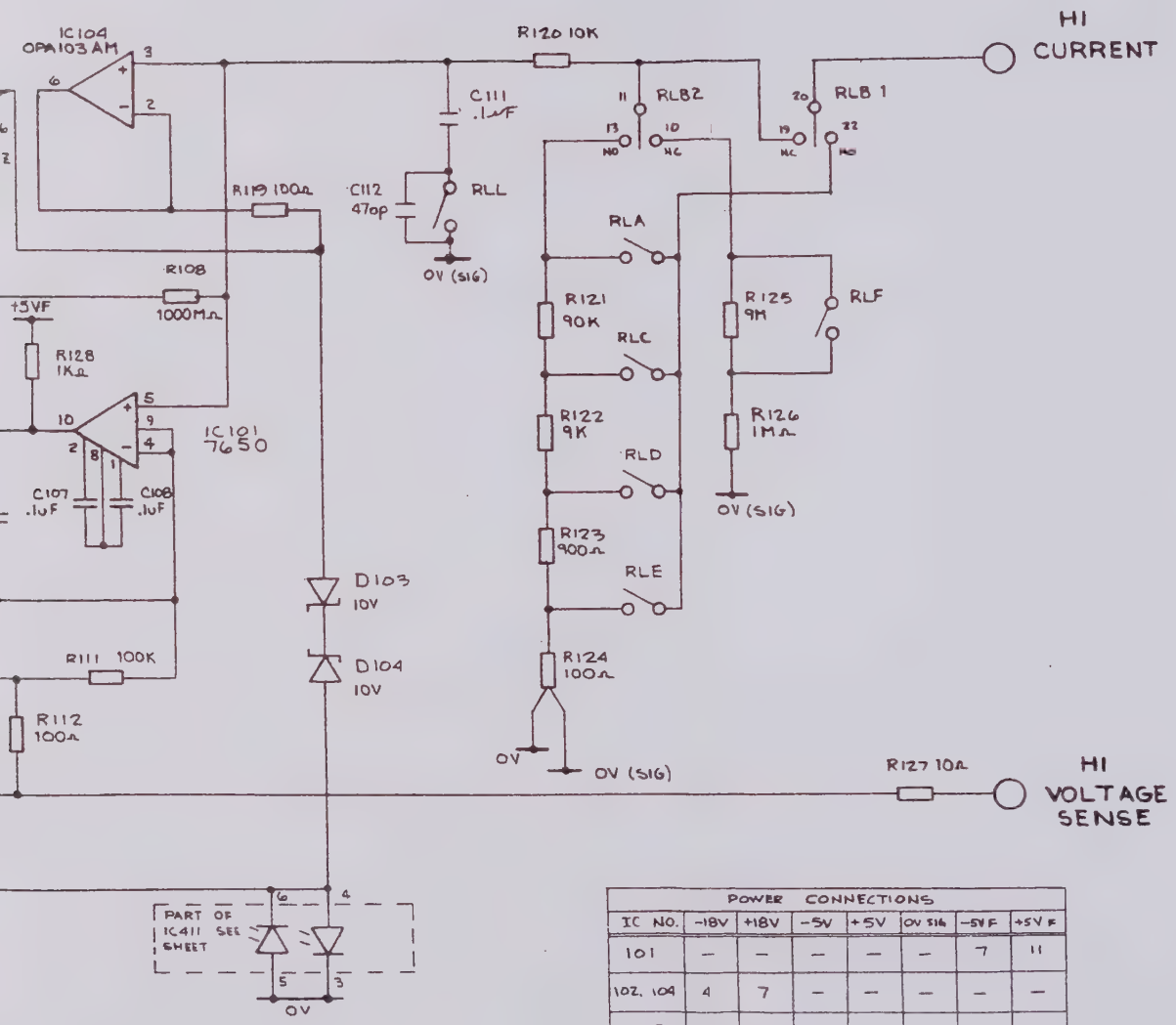
NOTES: (UNLESS OTHERWISE SPECIFIED)

1. FOR ASSY OF P.C.B. SEE 2724-700.



REVISIONS				
ECO	LTR	DESCRIPTION	DATE	APPROVED
0103	C	R101 WAS 1K IS 10K R106 WAS 20KΩ IS 4.7KΩ ADDED R128 DELETED D105 & D106 ADDED C112 C111 WAS .05μF C102 WAS 0.1μF IS 0.5μF	8-11-83	PWD
381	D	CHANGED R317 FROM 250K TO 249K Ω	3-19-84	

IC105
LM340LAZ



POWER CONNECTIONS							
IC NO.	-18V	+18V	-5V	+5V	OV SIG	-5V F	+5V F
101	—	—	—	—	—	7	11
102, 104	4	7	—	—	—	—	—
103	—	—	7	11	5	—	—

FIRST USED	NOT USED	LAST USED
IC101	—	IC106
R101		R128
RV101		RV103
C101		C112
D101		D106
RLA	RLK	RLL

TOLERANCES
X° = ± 30'
.XX = ± .03
.XXX = ± .010

MATERIAL

FINISH

BREAK ALL SHARP CORNERS AND EDGES. MACH SURFACES 94

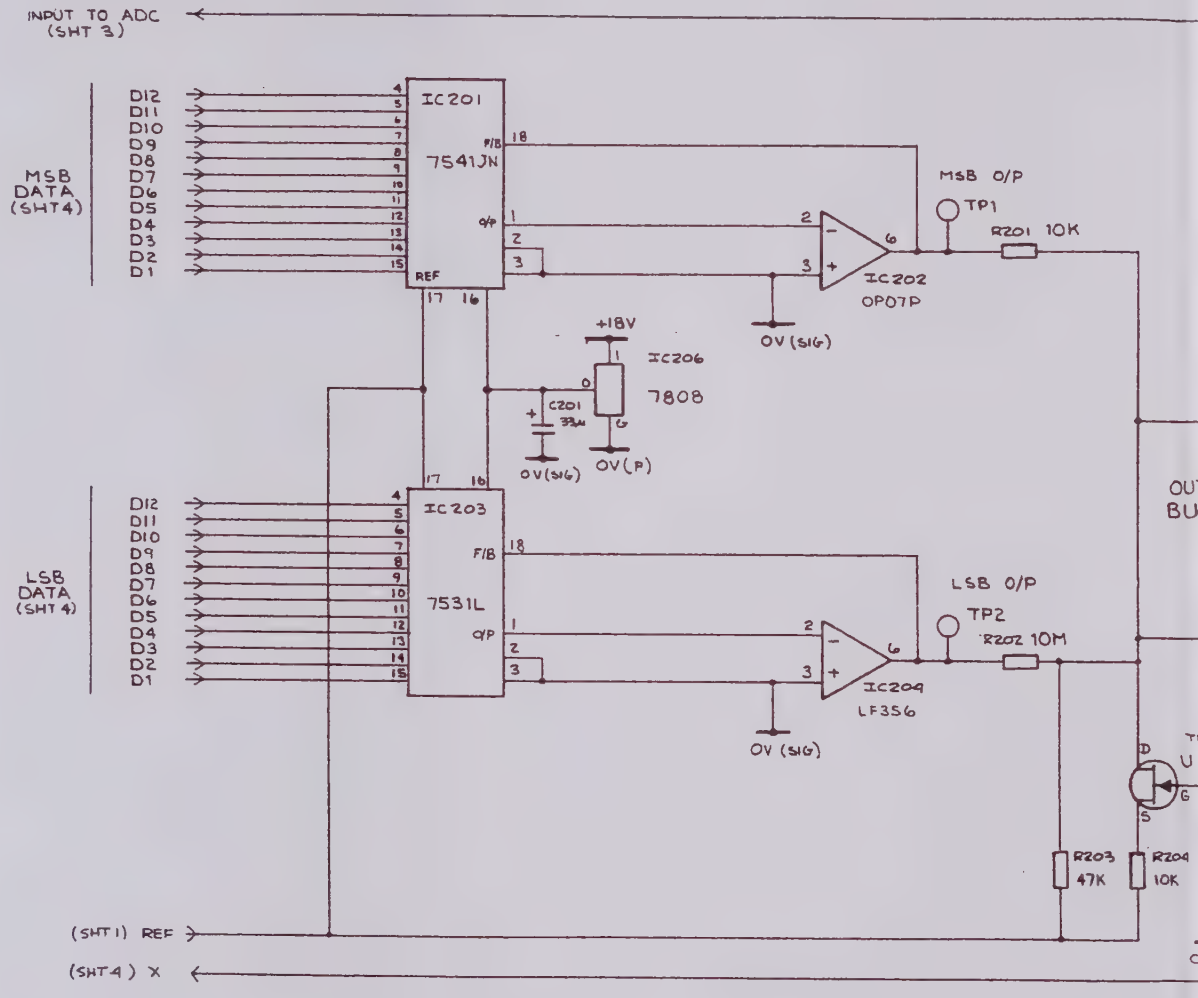
DRAWN RM	3/28/83	
CHECKED PW	4-10-83	
APPR PW	4-10-83	
STK NO		

Valhalla Scientific Inc.
SAN DIEGO, CA

ACTIVE OHMS SCHEMATIC
2724A

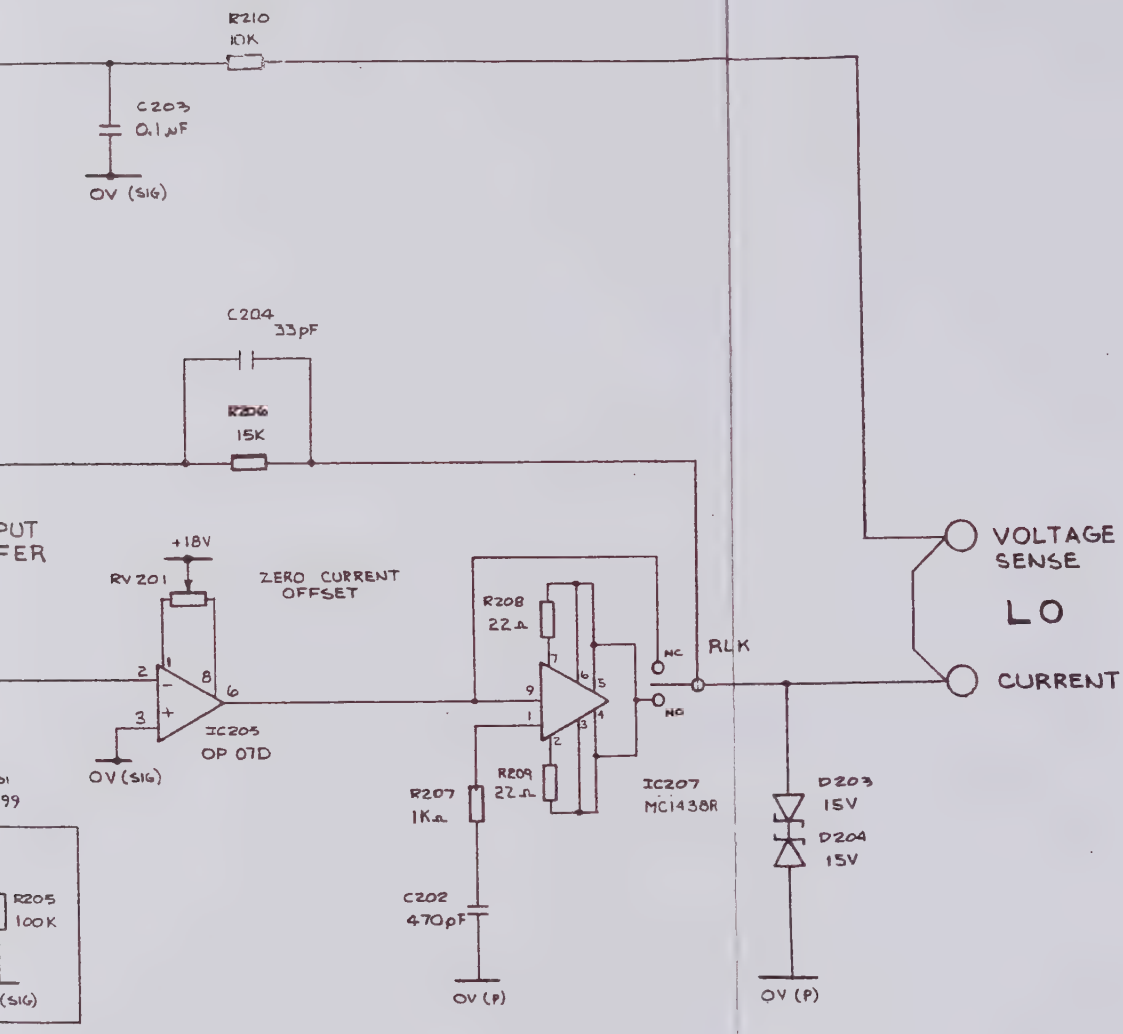
SCALE	CODE IDENT	SIZE	DRAWING NO	REV
SHEET 1 OF 7	53504	D	2724-070	D

NOTES: (UNLESS OTHERWISE SPECIFIED)



POWER CONNETIONS			
IC#	+18V	-18V	
201, 203	/	/	/
202, 204, 205	7	4	
207	8	CASE	/

REVISIONS				
ECO	LTR	DESCRIPTION	DATE	APPROVED
0103	C	DELETED D201 & D202 C204 ADDED 33pF	8-11-83	



FIRST USED	NOT USED	LAST USED
IC201		IC207
R201		R210
RV201		RV201
D201	D201, D202	D204
C201		C204
TR201		TR201
RLK		RLK

TOLERANCES: X = ± 30' .XX = ± 03 .XXX = ± .010

BREAK ALL SHARP CORNERS AND EDGES. MACH SURFACES 64

MATERIAL

FINISH

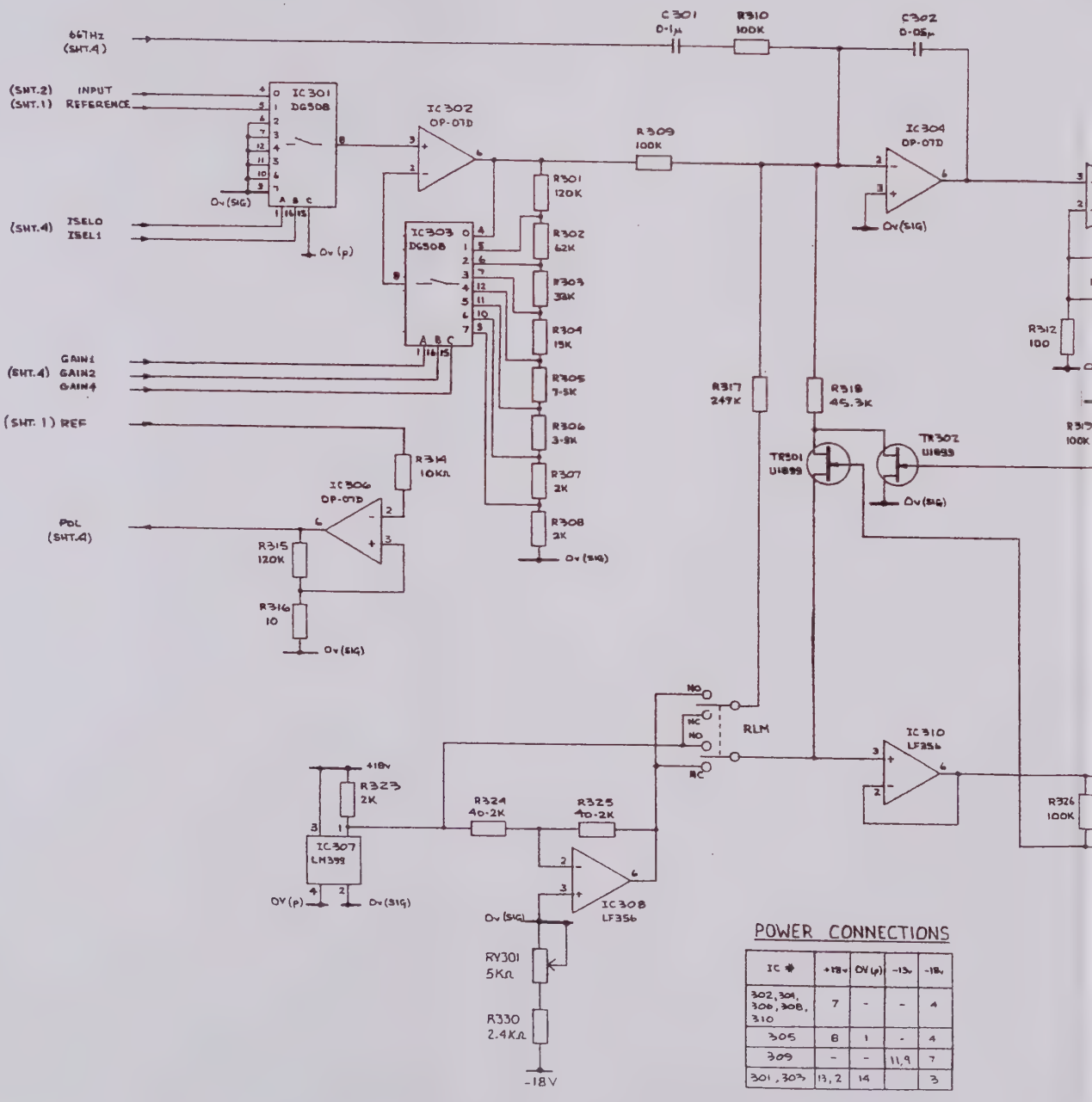
DRAWN RM	3/28/83	
CHECKED		
APPR		
STK NO		

Valhalla Scientific Inc.
SAN DIEGO, CA

MULTIPLYING D TO A CONVERTER - SCHEMATIC
2724A

SCALE	CODE IDENT	SIZE	DRAWING NO	REV
SHEET 2 OF 7	53504	D	2724-070	D

NOTES: (UNLESS OTHERWISE SPECIFIED)

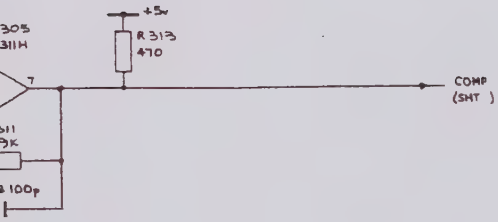


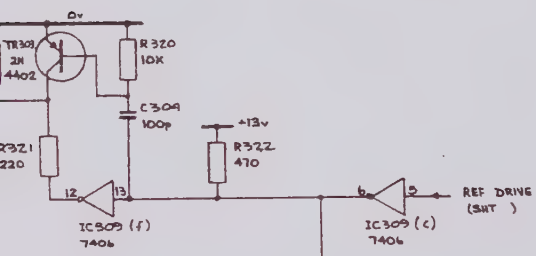
POWER CONNECTIONS

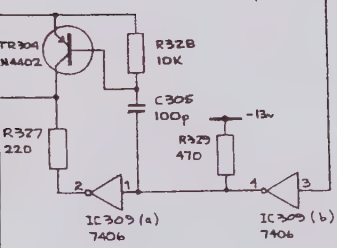
IC #	+18v	0V (p)	-13v	-18v
302, 304, 306, 308, 310	7	-	-	4
305	8	1	-	4
309	-	-	11,9	7
301, 303	13, 2	14		3

REVISIONS				
ECO	LTR	DESCRIPTION	DATE	APPROVED
0103	C	ADDED RV301 ADDED R330	8-11-83	RDJ

0331 D SEE PAGE 1 OF 7







FIRST USED	NOT USED	LAST USED
IC 301	——	IC 310
R301	——	R329
C301	——	C305
TR301	——	TR309
RLM	——	RLM

TOLERANCES
X° = ± 30'
.XX = ± .03
.XXX = ± 010

BREAK ALL SHARP CORNERS AND EDGES. MACH SURFACES 64

MATERIAL

FINISH

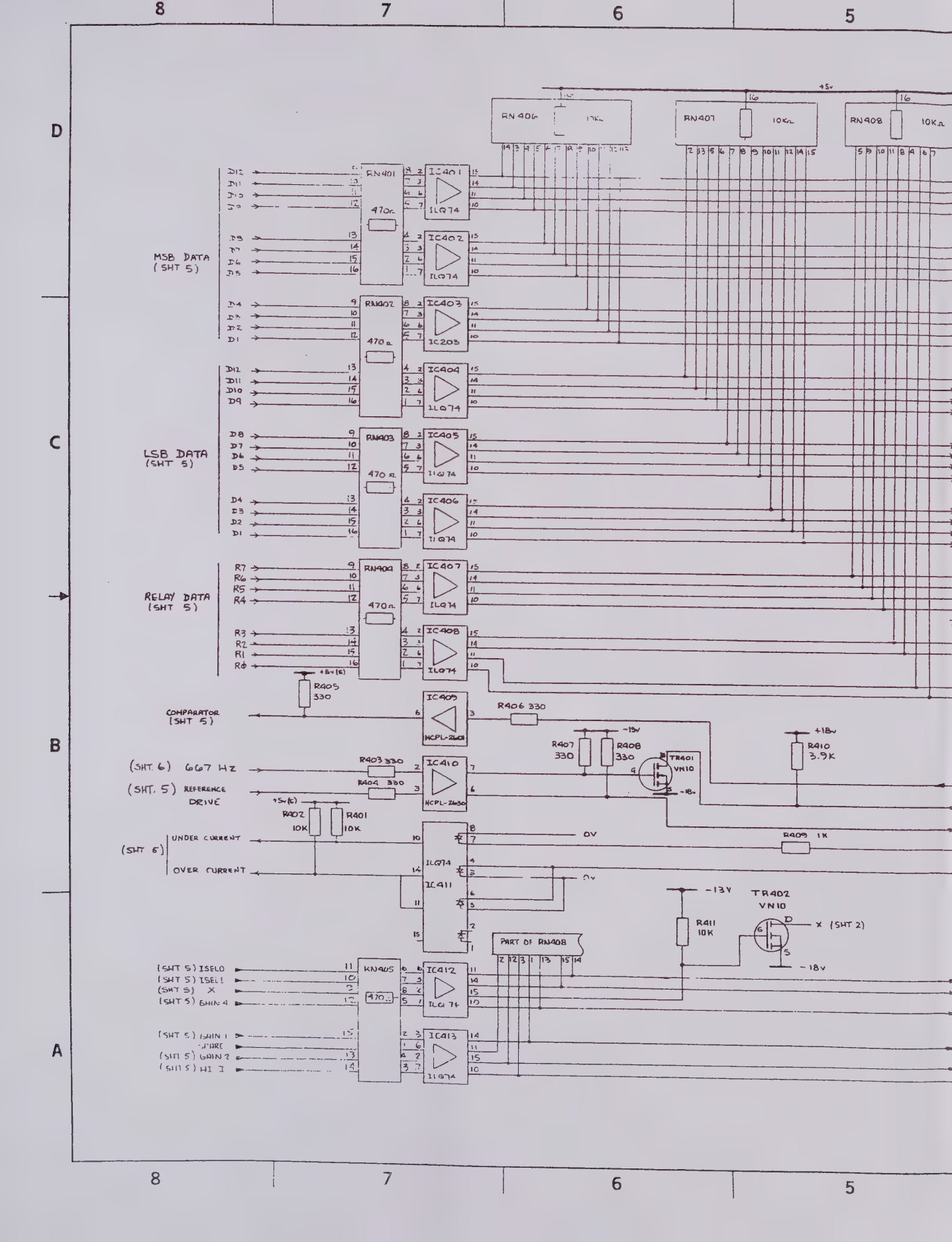
DRAWN	RDJ	4-12-83
CHECKED	PW	6-10-83
APPR	PW	6-10-83
STK NO		

Valhalla Scientific Inc.
SAN DIEGO, CA

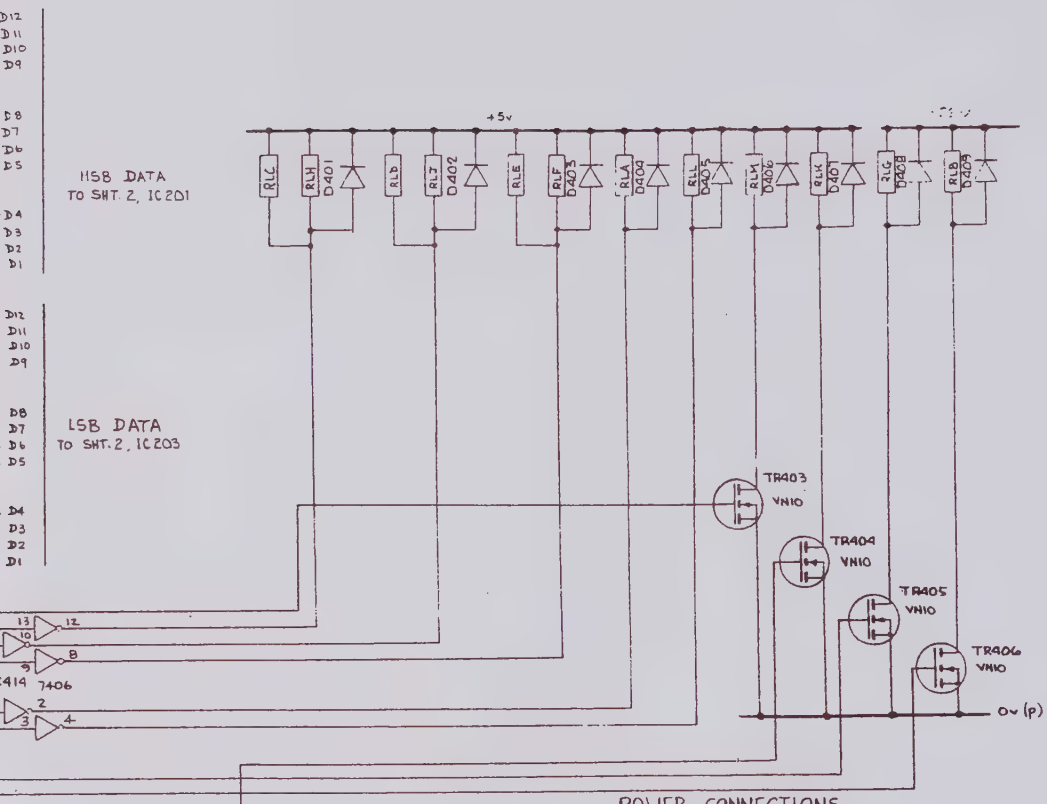
A-TO-D CONVERTOR
2724A

SCALE	CODE IDENT	SIZE	DRAWING NO	REV
	53504	D	2724-070	D

SHEET 3 OF 7


8
7
6
5
D
C
B
A
RN406
RN407
RN408
10KΩ
+5V
MSB DATA (SHT 5)
LSB DATA (SHT 5)
RELAY DATA (SHT 5)
RN401
RN402
RN403
RN404
RN405
470Ω
IC401
IC402
IC403
IC404
IC405
IC406
IC407
IC408
IC409
IC410
IC411
IC412
IC413
ILQ74
IC203
HCPL-2601
HCPL-2630
D12
D11
D10
D9
D8
D7
D6
D5
D4
D3
D2
D1
R7
R6
R5
R4
R3
R2
R1
R0
R405 330
COMPARATOR (SHT 5)
R406 330
-15V
R407 330
R408 330
TR401 VN10
+18V
R410 3.9K
(SHT 6) 667 HZ
(SHT 5) REFERENCE DRIVE
R403 330
R404 330
R402 10K
R401 10K
(SHT 6)
UNDER CURRENT
OVER CURRENT
0V
R409 1K
PART OF RN408
-13V
TR402 VN10
R411 10K
X (SHT 2)
-18V
(SHT 5) ISEL0
(SHT 5) ISEL1
(SHT 5) X
(SHT 5) GAIN 0
(SHT 5) GAIN 1
SPARE
(SHT 5) GAIN 2
(SHT 5) HI I

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
			8-11-83	



POWER CONNECTIONS

IC #	+5v(c)	0v(c)	+5v	0v(p)	-18v	-13v
401-408	1,4,5,8	-	-	9,12,13,16	-	-
409	7,8	5	2	-	-	—
410	1.4	-		-	5	8
411	-	9,12,13,16	-	-	-	-
414			14	7		
413	1,4,5,8	-	-	9,12,13,16	—	-
412	1,4,5,8	-	-	9,12,13	16	-

- COMP (SHT 3)
- 667 Hz (SHT 3)
- REF DRIVE (SHT 3)
- POL (SHT 3)
- D104 (SHT. 1)

- ISEL0 (SHT 3)
- ISEL1 (SHT 3)
- GAIN 4 (SHT 3)
- GAIN 1 (SHT 3)
- GAIN 2 (SHT 3)

FIRST USED	NOT USED	LAST USED
IC401		IC414
R401		R411
RN401		RN406
D401		D409
TR401		TR406

MATERIAL

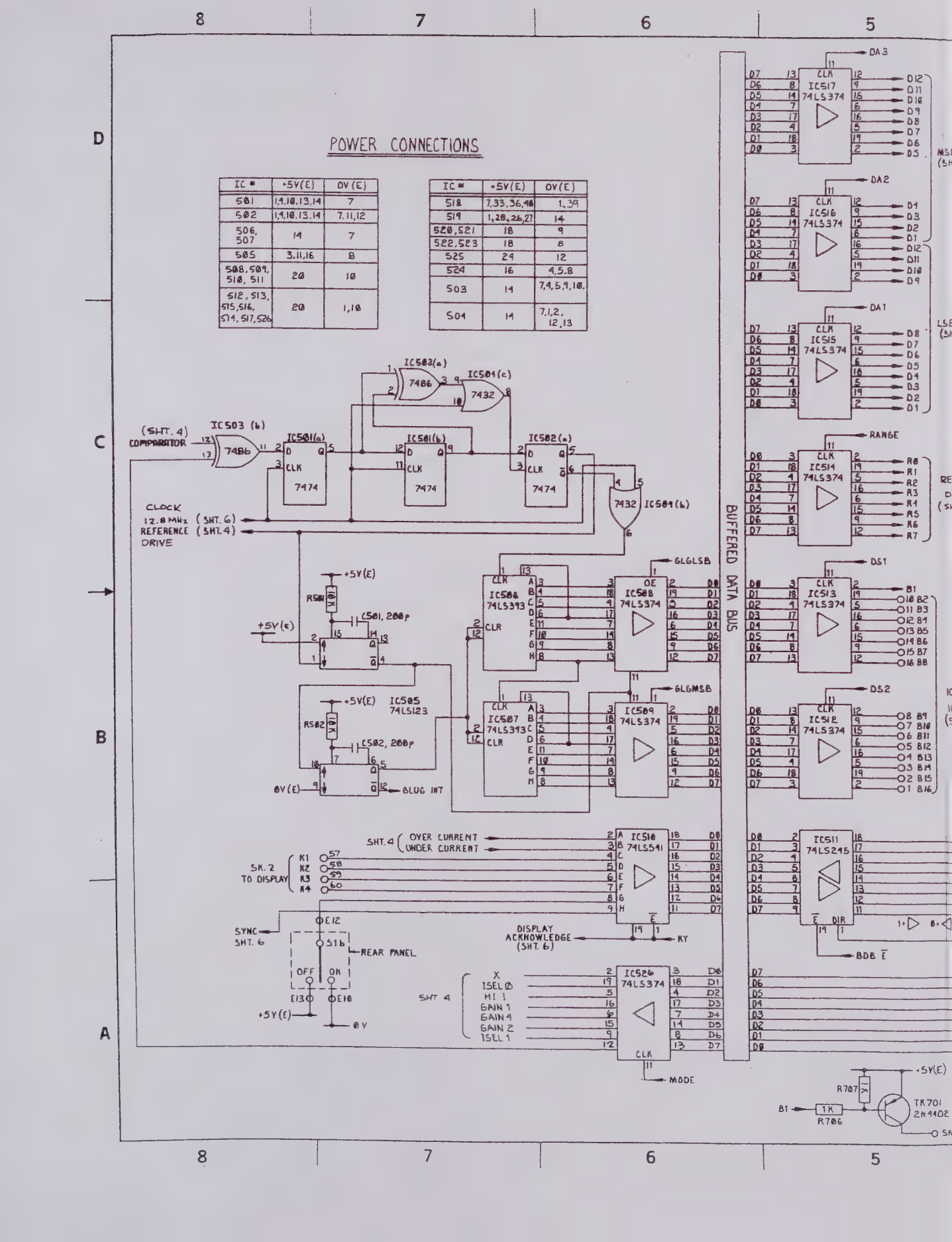
FINISH

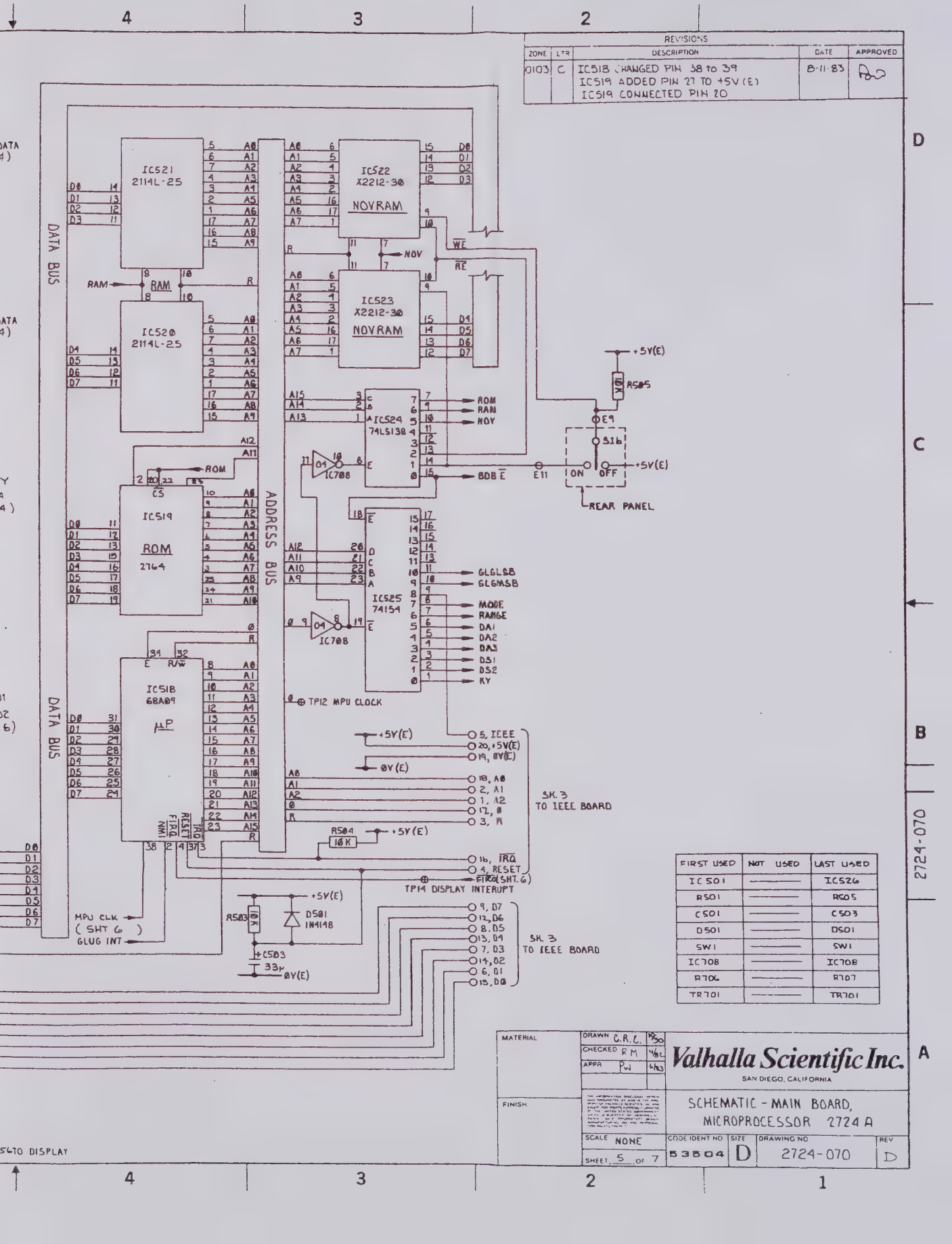
DRAWN		
CHECKED		11/11
APPR		11/11

Valhalla Scientific Inc.
SAN DIEGO, CALIFORNIA

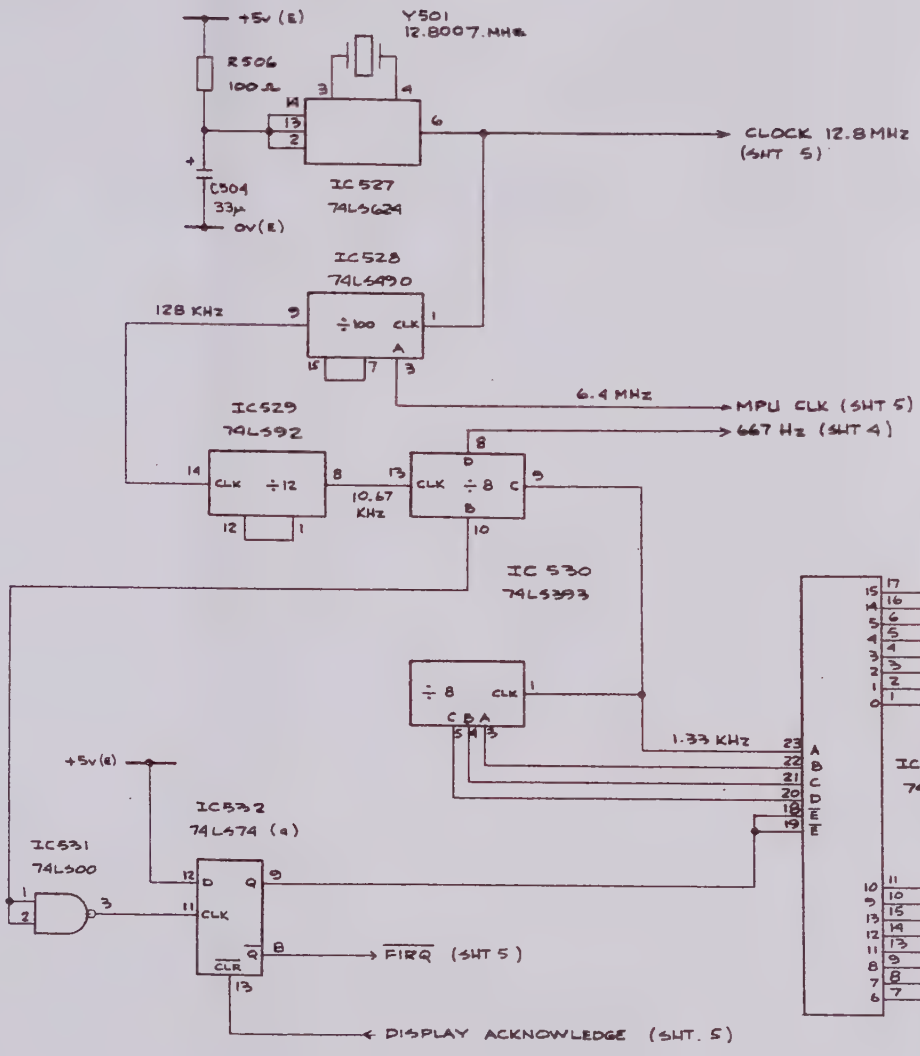
SCHEMATIC - MAIN BOARD, LOATING LOGIC - 2724A

SCALE	CODE IDENT NO	SIZE	DRAWING NO	REV
SHEET 4 OF 7	53504	D	2724-070	D


POWER CONNECTIONS
IC # | +5V(E) | 0V(E)
501 | 1,4,10,13,14 | 7
502 | 1,4,10,13,14 | 7,11,12
506, 507 | 14 | 7
505 | 3,11,16 | 8
508,509, 510, 511 | 20 | 10
512, 513, 515,516, 514, 517,526 | 20 | 1,10
IC # | +5V(E) | 0V(E)
518 | 7,33,36,48 | 1,39
519 | 1,28,26,27 | 14
520,521 | 18 | 9
522,523 | 18 | 8
525 | 29 | 12
524 | 16 | 4,5,8
503 | 14 | 7,4,5,9,10,
504 | 14 | 7,1,2, 12,13
IC503 (b)
7486
IC501(a)
IC501(b)
IC501(c)
IC502(a)
IC504(b)
7474
7432
(SHT. 4) COMPARATOR
CLOCK 12.8 MHz (SHT. 6) REFERENCE (SHT. 4) DRIVE
+5V(E)
R501 10K
C501, 200p
R502 10K
C502, 200p
IC505 74LS123
0V(E)
BLDG INT
IC506 74LS393
IC507 74LS393
IC508 74LS374
IC509 74LS374
GLGLSB
GLGMSB
CLR
BUFFERED DATA BUS
IC517 74LS374
IC516 74LS374
IC515 74LS374
IC514 74LS374
IC513 74LS374
IC512 74LS374
DA3
DA2
DA1
RANGE
DS1
DS2
MSB (SH
LSB (SH
SHT. 4 OVER CURRENT UNDER CURRENT
IC510 74LS541
SK. 2 TO DISPLAY
K1 K2 K3 K4
SYNC SHT. 6
E12
S1b
REAR PANEL
OFF ON
E13 E10
DISPLAY ACKNOWLEDGE (SHT. 6)
KY
IC511 74LS245
BDB Ē
SHT 4
X ISEL0 MI 1 GAIN 1 GAIN 4 GAIN 2 ISEL 1
IC526 74LS374
MODE
R707 1K
R706 1K
TR701 2N4402
B1

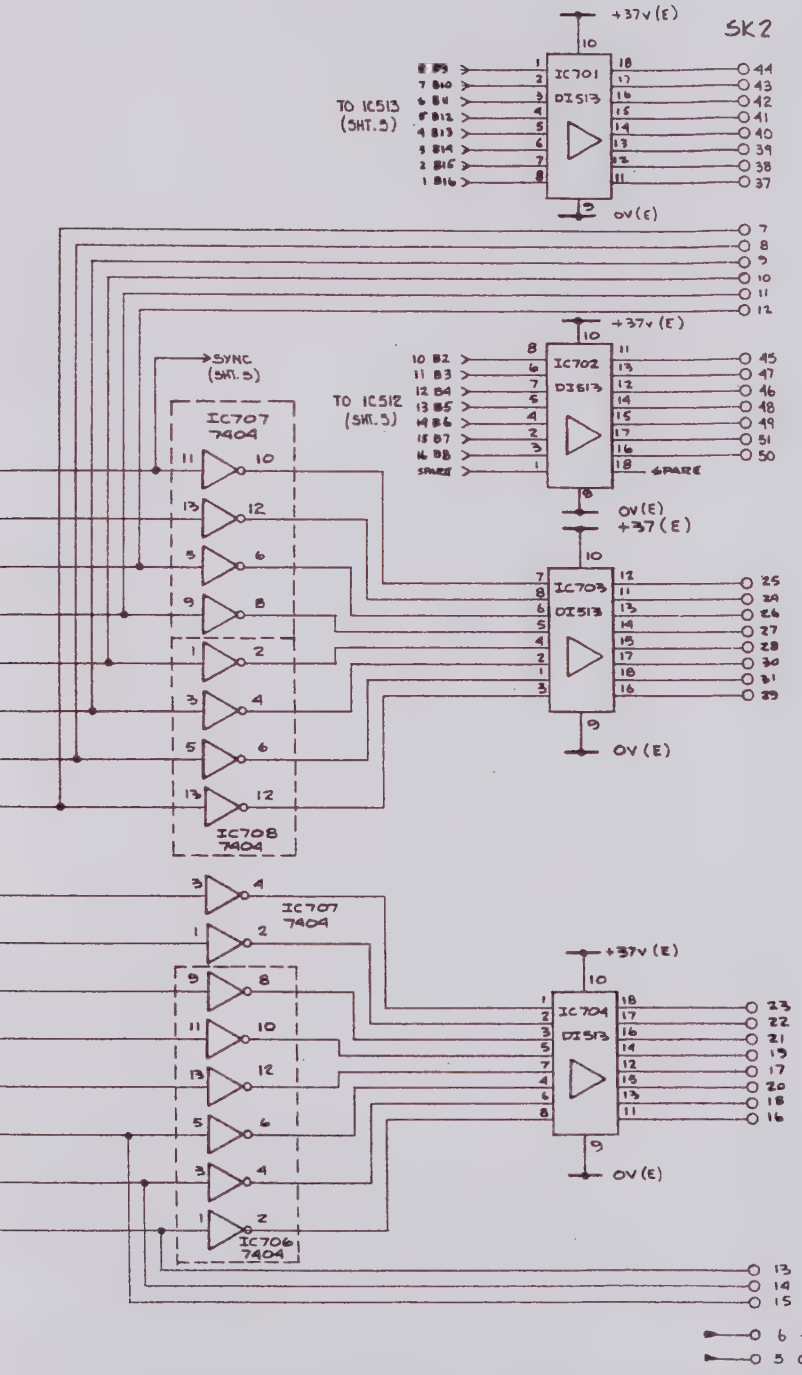

REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
0103 | C | IC518 CHANGED PIN 38 to 39
IC519 ADDED PIN 27 TO +5V(E)
IC519 CONNECTED PIN 20 | 8-11-83
IC521 2114L-25
IC522 X2212-30 NOVRAM
IC523 X2212-30 NOVRAM
IC520 2114L-25
IC524 74LS138
IC519 ROM 2764
IC518 6802 µP
IC525 74154
IC708
DATA BUS
ADDRESS BUS
RAM
ROM
NOV
WE
RE
+5V(E)
R505
S16
ON OFF
REAR PANEL
BDB E
GLGLSB
GLGMSB
MODE
RANGE
DA1
DA2
DA3
DS1
DS2
KY
TP12 MPU CLOCK
5, IEEE
20, +5V(E)
19, 0V(E)
18, A0
2, A1
1, A2
17, Ø
3, R/W
SK.3 TO IEEE BOARD
R504 10K
16, IRQ
4, RESET
TP14 DISPLAY INTERUPT
MPU CLK (SHT 6)
GLUG INT
R503 10K
D501 IN4148
C503 33µ
9, D7
12, D6
8, D5
13, D4
7, D3
14, D2
6, D1
15, D0
SK. 3 TO IEEE BOARD
TO DISPLAY
FIRST USED | NOT USED | LAST USED
IC501 | IC526
R501 | R505
C501 | C503
D501 | D501
SW1 | SW1
IC708 | IC708
R706 | R707
TR701 | TR701
MATERIAL
FINISH
DRAWN C.R.L. 8/30
CHECKED R M 9/82
APPR P.W 9/83
Valhalla Scientific Inc.
SAN DIEGO, CALIFORNIA
SCHEMATIC - MAIN BOARD, MICROPROCESSOR 2724 A
SCALE NONE
CODE IDENT NO 53804
SIZE D
DRAWING NO 2724-070
REV D
SHEET 5 OF 7
2724-070

NOTES: (UNLESS OTHERWISE SPECIFIED)



POWER CONNECTIONS		
IC NO.	+5V(E)	0V (E)
531, 704-8	14	7
527	9	1,5,7
528	16	2,9,8,12,14
529	5	4,7,10
530	14	2.7.12
532	2,10,4,14	7
705	24	12

REVISIONS				
ECO	LTR	DESCRIPTION	DATE	APPROVED
0103	C		8-11-83	



FIRST USED	NOT USED	LAST USED
IC701		IC708
IC527		IC532
R506		R506
C504		C509
Y501		Y501

TOLERANCES: X = ± 30' .XX = ± .03 .XXX = ± .010

BREAK ALL SHARP CORNERS AND EDGES. MACH SURFACES 64

MATERIAL

FINISH

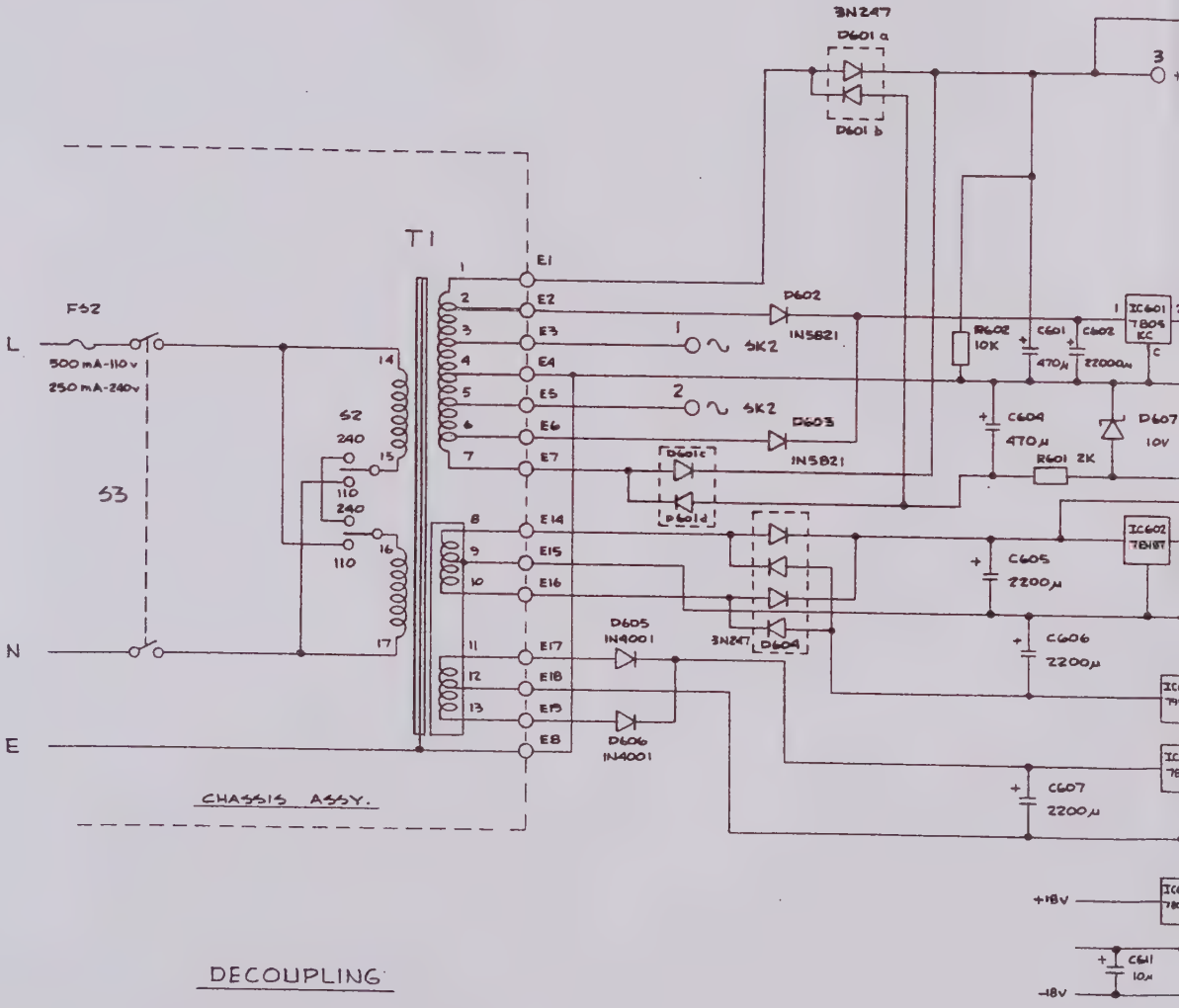
DRAWN WN	5-10-83	
CHECKED PW	6-10-83	
APPR PW	6-10-83	
STK NO		

Valhalla Scientific Inc.
SAN DIEGO, CA

SCHEMATIC, MAIN BOARD CLOCK

SCALE	CODE IDENT	SIZE	DRAWING NO	REV
SHEET 6 OF 7	53504	D	2724-070	D

NOTES: (UNLESS OTHERWISE SPECIFIED)



DECOUPLING

C901 , -13V	C908 , +18V
C902 , -13V	C909 , +18V
C903 , -18V	C910 , +18V
C904 , -18V	C911 , +18V
C905 , -18V	C912 , +18V
C906 , +5V	C913 - 923, +5V (E)
C907 , +5V	

REVISIONS				
ECO	LTR	DESCRIPTION	DATE	APPROVED
0103	C		8-11-83	PW

→ +37v (E)

v (E) SK2

→ +5v (E)

C603
220µ

→ 0v (E)

4 SK2

5 −10v SK2

→ +22v

→ +18v

C608
10µ

→ 0v

C609
10µ

→ −18v

→ −13v

C610
33µ

→ +5v

C612
10µ

→ 0v

C613
10µ

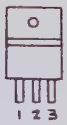
→ −5v

COMPONENT REFERENCE DATA

IC601

BOTTOM VIEW

1. INPUT
2. OUTPUT
3. GROUND



1. GROUND
2. INPUT
3. OUTPUT

IC603

1. INPUT
2. GROUND
3. OUTPUT

IC602
604
605

IC606

BOTTOM VIEW

1. GROUND
2. INPUT
3. OUTPUT

FIRST USED	NOT USED	LAST USED
IC601		IC606
R601		R602
D601		D607
C601		C613
E1	E9 - E13	E19
FS2		FS2
T1		T1

TOLERANCES
X = ± 30'
.XX = ± .03
.XXX = ± .010

BREAK ALL SHARP CORNERS AND EDGES. MACH SURFACES 64 ✓

MATERIAL

FINISH

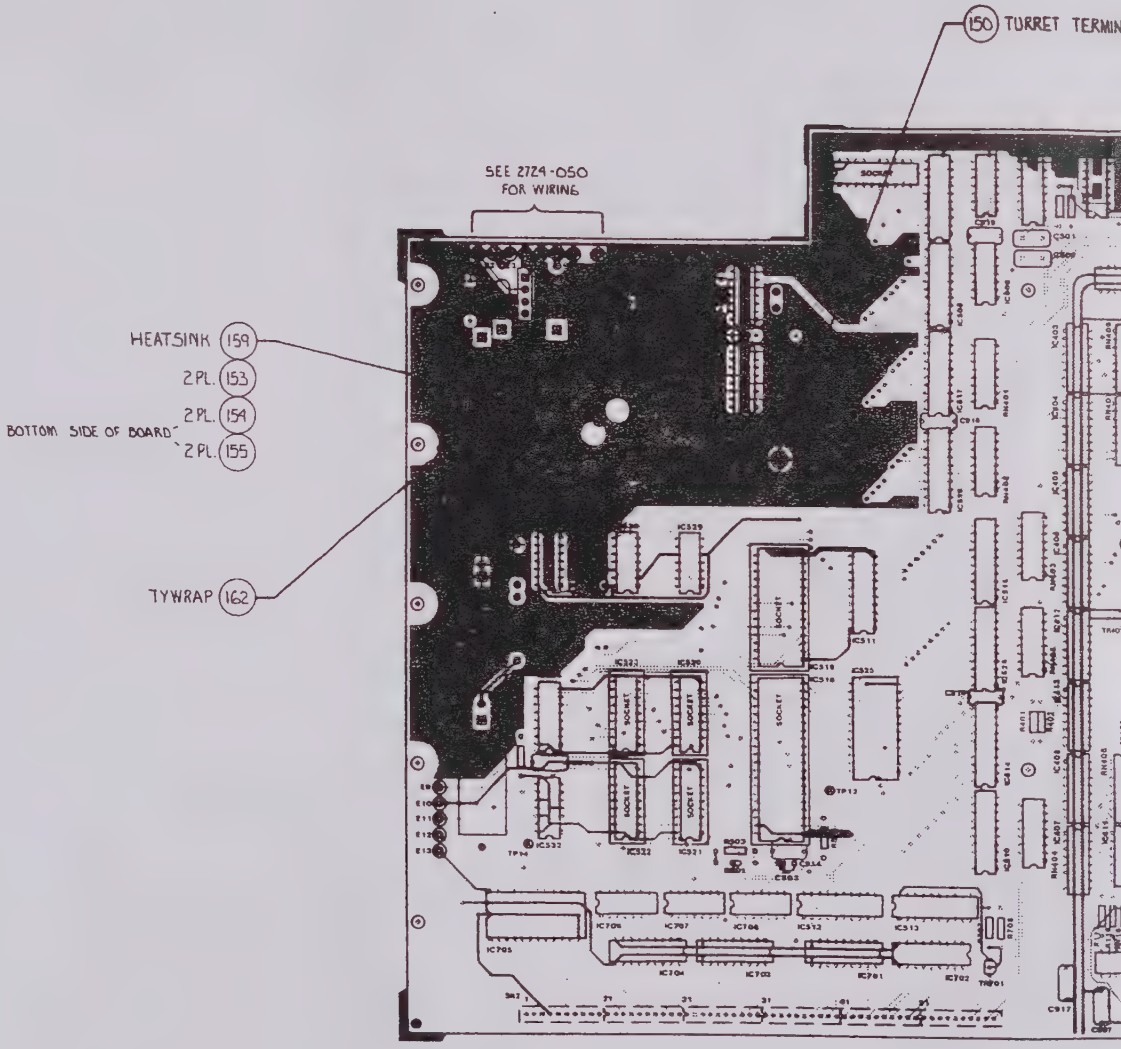
DRAWN WN	5-11-83	
CHECKED PW	6-10-83	
APPR PW	6-10-83	
STK NO		

Valhalla Scientific Inc.
SAN DIEGO, CA

SCHEMATIC MAIN BD. 2724A

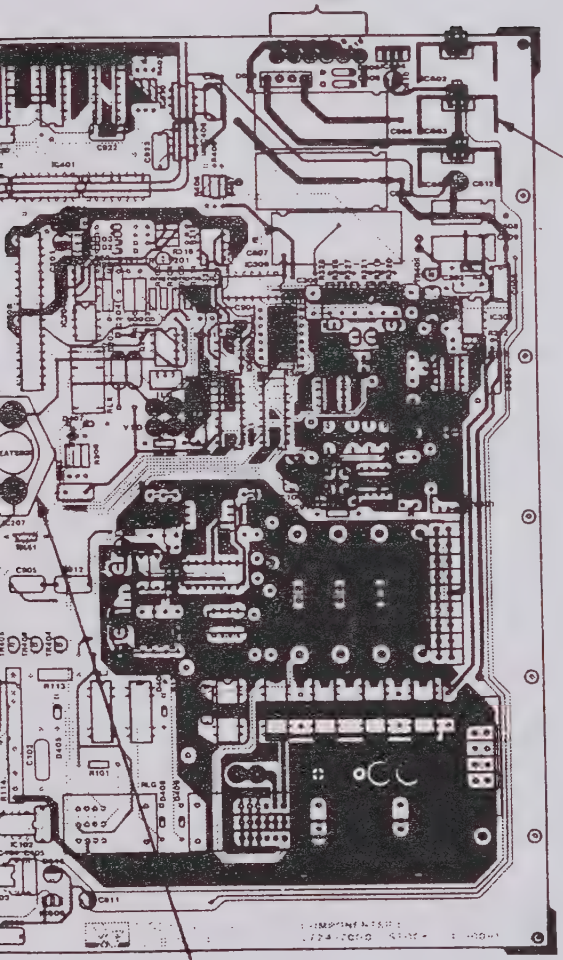
SCALE	CODE IDENT	SIZE	DRAWING NO	REV
SHEET 7 OF 7	53504	D	2724 - 070	D

NOTES:
1. FOR PARTS LIST SEE SHTS 1-8 OF 2724-600.



REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
189	D	CHG. VALUE OF Y501 FROM 2.8 TO 12.8007 PL	12-13-83	POW
175	E	SEE ECO CRE	1-17-84	POW
317	F	CHG. RELAY #77 WPW	3-14-84	PL
381	G	NO CHANGE TO THIS DRAWING		

SEE 2724-050 FOR WIRING

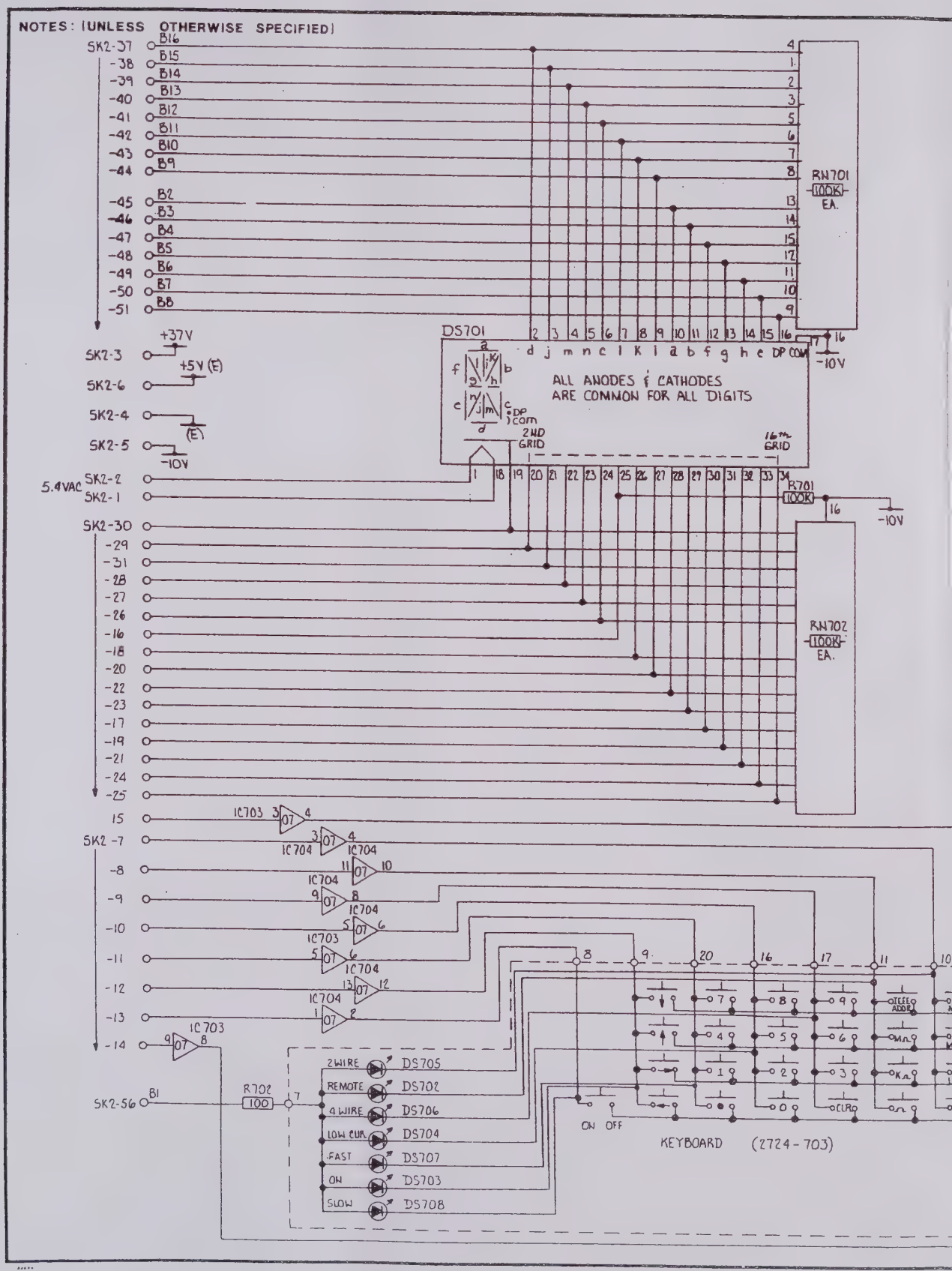


(158) HEATSINK
(152) 3 PL.
(156) 3 PL.
(157) 3 PL.

(160) HEATSINK
(153) 2 PL.
(154) 2 PL.
(155) 2 PL.

BOTTOM SIDE OF BOARD

MATERIAL: SEE PARTS LIST	DRAWN RM	Valhalla Scientific Inc. SAN DIEGO, CALIFORNIA	
	CHECKED		
	APPR		
FINISH: ~		P.C.B. ASSY - MAIN	
	SCALE 1/1	CODE IDENT NO 83504	SIZE D
	SHEET 9 OF 9	DRAWING NO 2724-600	REV G


NOTES: (UNLESS OTHERWISE SPECIFIED)
SK2-37 B16
-38 B15
-39 B14
-40 B13
-41 B12
-42 B11
-43 B10
-44 B9
-45 B2
-46 B3
-47 B4
-48 B5
-49 B6
-50 B7
-51 B8
RN701 100K EA.
DS701
ALL ANODES & CATHODES ARE COMMON FOR ALL DIGITS
2ND GRID
16TH GRID
+37V
SK2-3
+5V (E)
SK2-6
SK2-4
(E)
SK2-5
-10V
5.4VAC SK2-2
SK2-1
SK2-30
-29
-31
-28
-27
-26
-16
-18
-20
-22
-23
-17
-19
-21
-24
-25
RN702 100K EA.
15
SK2-7
-8
-9
-10
-11
-12
-13
-14
IC703
IC704
2WIRE DS705
REMOTE DS702
4 WIRE DS706
LOW CUR DS704
FAST DS707
ON DS703
SLOW DS708
SK2-56 B1
R702 100
ON OFF
KEYBOARD (2724-703)

REVISIONS				
ECO	LTR	DESCRIPTION	DATE	APPROVED
0099	A	CHANGED PIN ASSIG. 29, 30, 31	8-9-83	PDQ

POWER CONNECTIONS

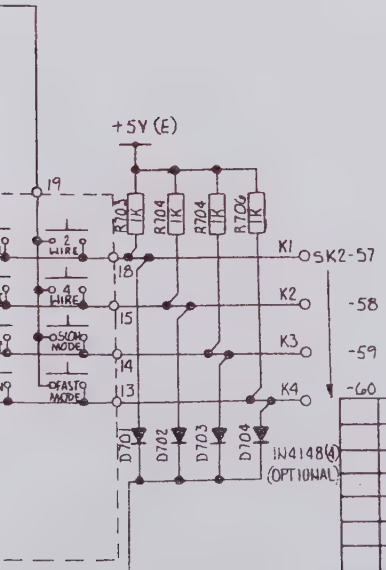
IC NO.	+5V (E)	GND (E)
703, 704	14	7

REF. DES.

NOT USED	LAST USED
	IC 704 DS 704 D 704 R 706 RN 702

NOTES:

1. UNLESS OTHERWISE NOTED:
   A. ALL RESISTORS ARE 1/4 W, 5%
2. FOR ASSY. OF DISPLAY P.C.B. SEE 2724-601.
3. FOR ASSY OF KEYBOARD SEE 2724-603



DASH NO	QTY REQD	NEXT ASSEMBLY	USED ON

TOLERANCES
X = ± 30'
.XX = ± .03
.XXX = ± .010

BREAK ALL SHARP CORNERS AND EDGES. MACH SURFACES 64

MATERIAL ~

FINISH ~

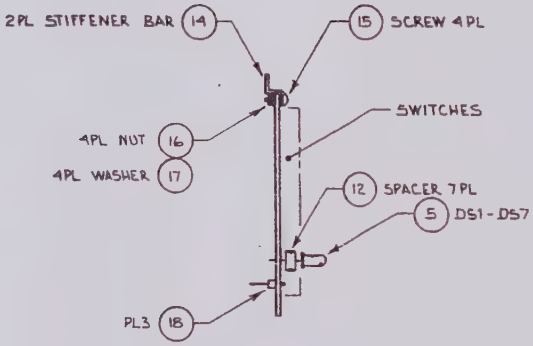
DRAWN	JP	8-10-83
CHECKED	PW	8-10-83
APPR	PW	9-8-83
STK NO	—	
SCALE	~	
SHEET	1 OF 1	

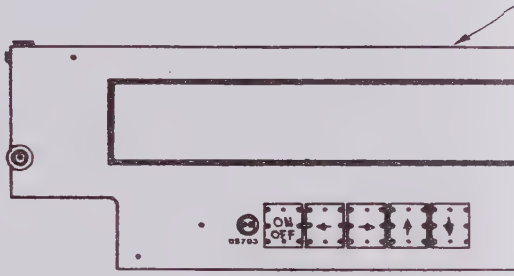
Valhalla Scientific Inc.
SAN DIEGO, CA

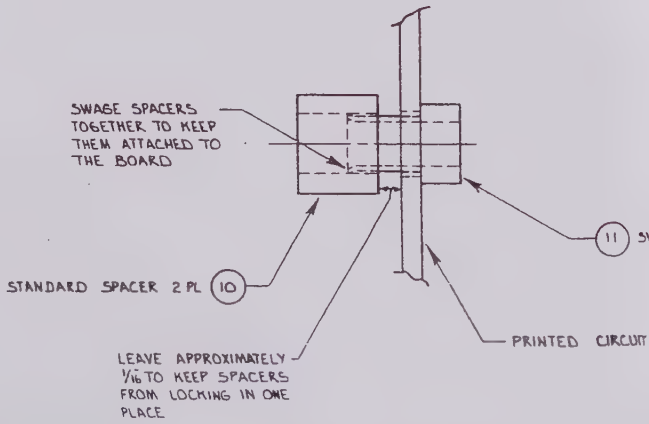
SCHEMATIC-DISPLAY

CODE IDENT	SIZE	DRAWING NO	REV
53504	D	2724-071	A

NOTES: (UNLESS OTHERWISE SPECIFIED)



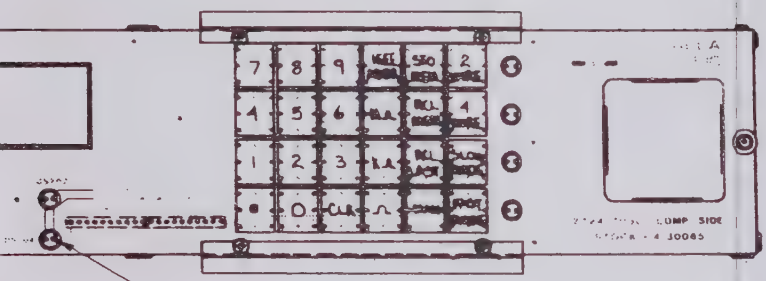



SWAGE SPACERS TOGETHER TO KEEP THEM ATTACHED TO THE BOARD
11
STANDARD SPACER 2 PL 10
LEAVE APPROXIMATELY 1/16 TO KEEP SPACERS FROM LOCKING IN ONE PLACE
PRINTED CIRCUIT

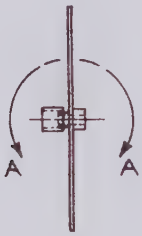
VIEW A-A SCALE 4:1

REVISIONS				
ECO	LTR	DESCRIPTION	DATE	APPROVED
244	C	REDRAWN CRE	1-6-84	
285	D	SEE ECO CRE	1-20-84	

(3) PRINTED CIRCUIT BOARD



NOTE: FLAT SIDE OF
LED GOES TO THE SQUARE PAD



GE SPACER 2PL

BOARD

DASH NO	QTY REQD	NEXT ASSEMBLY	USED ON
	1	2724-400	2724

TOLERANCES
X = ± 30'
.XX = ± 03
XXX = ± 010

BREAK ALL SHARP CORNERS AND EDGES. MACH SURFACES 63

MATERIAL

FINISH

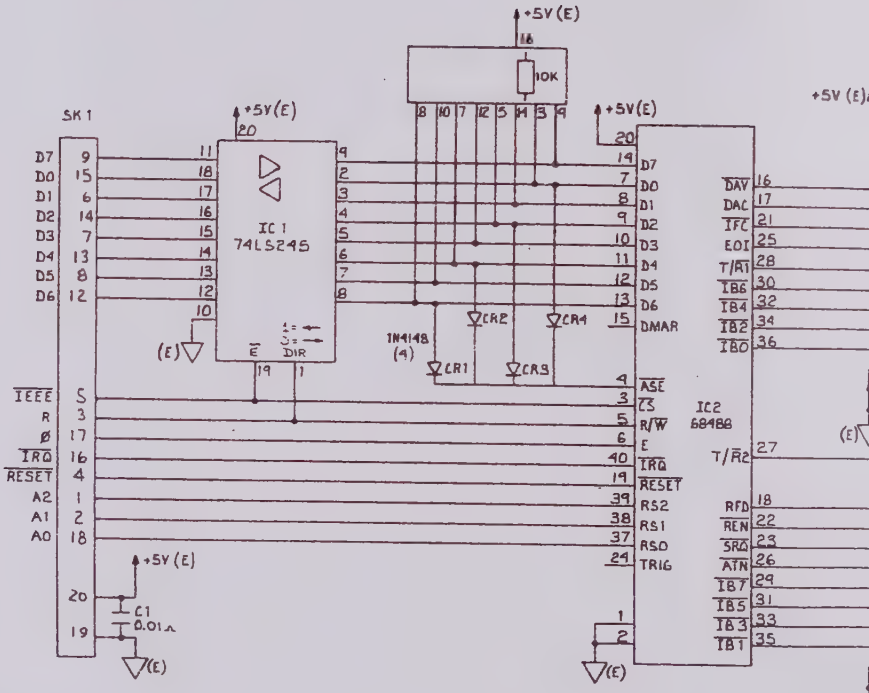
DRAWN CRE 1-6-84
CHECKED [illegible] 1-6-84
APPR [illegible] 1-6-84
STK NO

Valhalla Scientific Inc.
SAN DIEGO, CA

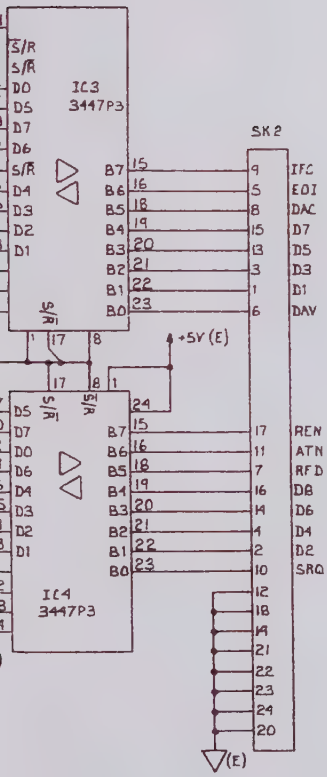
2724 KEYBOARD ASSY.

SCALE 1:1
SHEET 2 OF 2

CODE IDENT	SIZE	DRAWING NO	REV
53504	D	2724-603	D


+5V(E)
10K
SK1
IC1
74LS245
IC2
68488
IN4148
(4)
CR1
CR2
CR3
CR4
C1
0.01μ
D7
D0
D1
D2
D3
D4
D5
D6
DMAR
ASE
CS
R/W
E
IRQ
RESET
RS2
RS1
RS0
TRIG
T/R1
T/R2
DAV
DAC
IFC
EOI
ATN
REN
SRQ
RFD
IEEE
R
Ø
A2
A1
A0
DIR

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



MATERIAL	DRAWN C.R.E.	Valhalla Scientific Inc.				
	CHECKED	SAN DIEGO, CALIFORNIA				
	APPR.					
FINISH		SCHEMATIC. IEEE-488 INTERFACE BOARD				
	SCALE NONE	CODE IDENT NO	SIZE	DRAWING NO	REV	
	SHEET 1 OF 1	53504	D	2724-072	X	

2724-072 X

4

D

C

B

A

ASSEMBLY PROCEEDURE

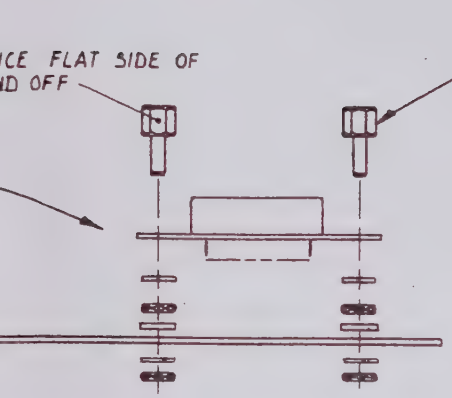
ASSEMBLE ITEMS 18,16,20 - 21 TIGHTEN HEX NUTS. THEN ASSEMBLE ITEM 22,19 AND THE REMAINDER OF 18. TIGHTEN ALL HEX NUTS AND SOLDER PINS OF ITEM 16 TO P.C.B.

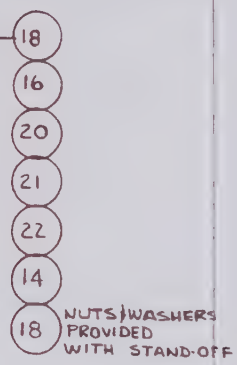
Optico

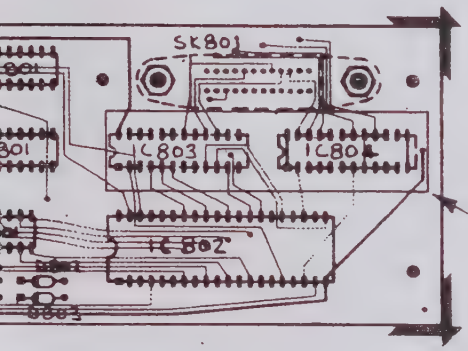
4

3

REVISIONS				
LTR	DESCRIPTION	DATE	APPROVED
A	ADDED EXPANSION BD. W.P.W. 8-3-83	8-8-83	PW
B	LENGTHEN ITEM 23 (NOT SHOWN)	11-11-83	PDW
C	P/L CHANGE ITEM 12 TO 5-10271	2-27-84	R
473 D	CHANGED P/L - DELETE #23 SCREWS. RDN	6-7-84	R







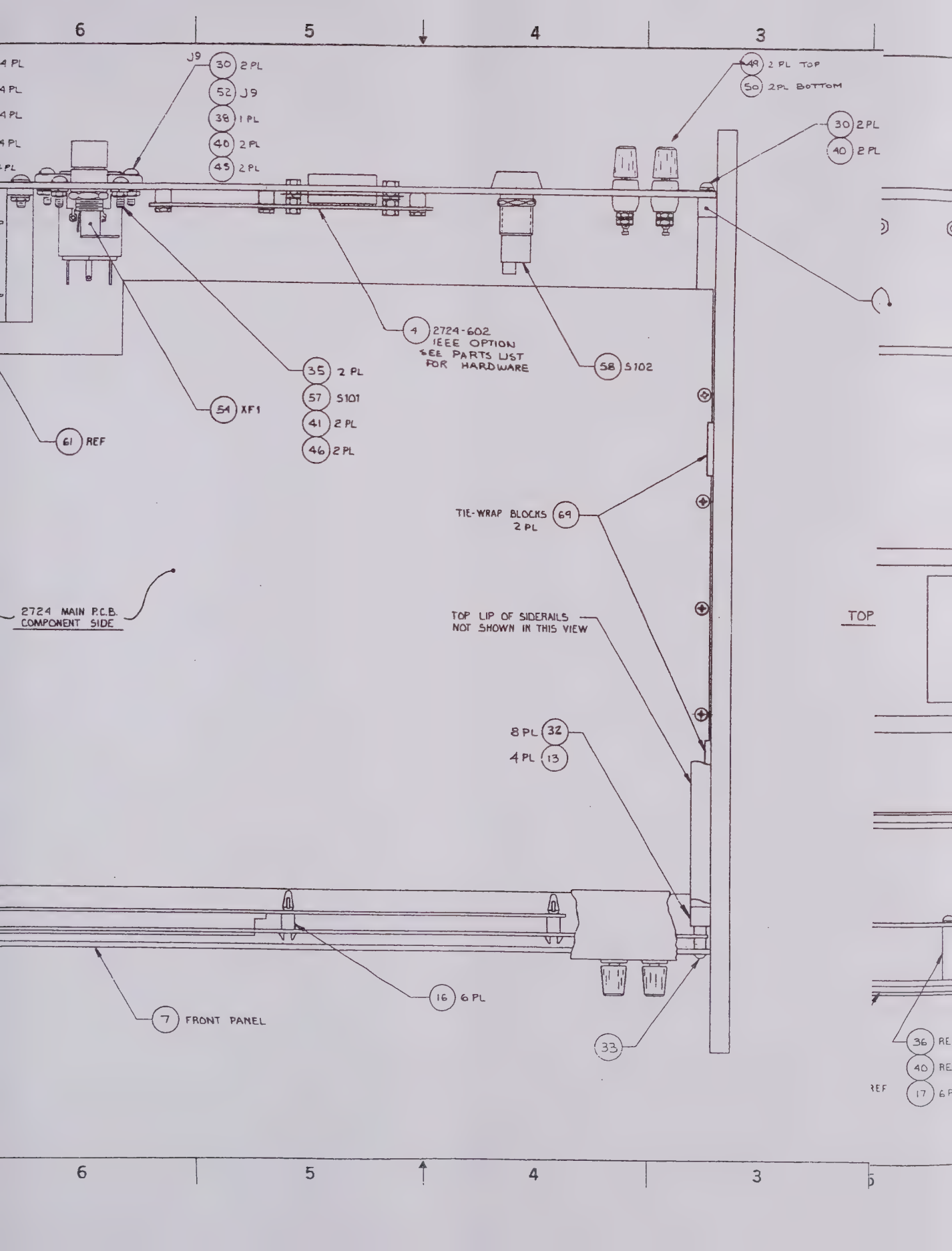
OWN IS ASSY 2724-602
CLAD SHOWN IS FAR SIDE.

INSTALL EXPANSION BD. ASSY (2724-604)
IN PLACE OF IC 803 & 804.
MAKE SURE PIN 1'S ON IEEE BD.
AND PIN 1'S ON EXPANSION BD. LINE UP
(ONLY IF IC803 & IC804 ARE NOT
MOUNTED ON IEEE BOARD.)

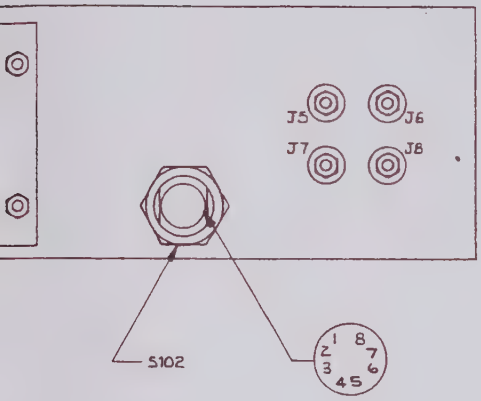
2. FOR PARTS LIST SEE SHT 1.
1. FOR SCHEMATIC SEE 2724-072.

NOTES:

MATERIAL	DRAWN CRE 3/82	Valhalla Scientific Inc.	
	CHECKED RM 5/82	SAN DIEGO, CALIFORNIA	
	APPR. PW 8/83		
FINISH	THE INFORMATION DISCLOSED HEREIN WAS ORIGINATED BY AND IS THE PROPERTY OF VALHALLA SCIENTIFIC INC AND EXCEPT FOR RIGHTS EXPRESSLY GRANTED TO THE UNITED STATES GOVERNMENT VALHALLA SCIENTIFIC INC RESERVES ALL PATENT SALE PROPRIETARY DESIGN MANUFACTURING USE AND REPRODUCTION RIGHTS THEREIN	ASSEMBLY - IEEE	
	SCALE 1/1	CODE IDENT NO. 53504 / SIZE C / DRAWING NO. 2724-602	REV. D
	SHEET 2 OF 2		

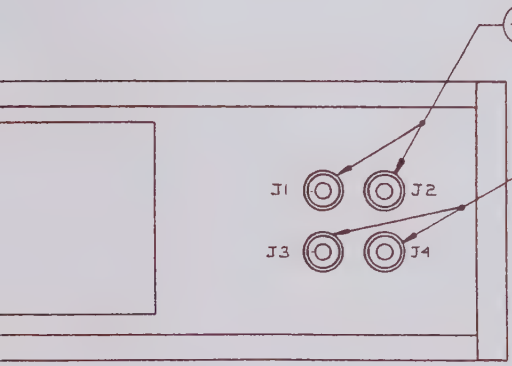

6
5
4
3
J9
30 2 PL
52 J9
38 1 PL
40 2 PL
45 2 PL
49 2 PL TOP
50 2 PL BOTTOM
30 2 PL
40 2 PL
4 2724-602 IEEE OPTION SEE PARTS LIST FOR HARDWARE
58 S102
35 2 PL
57 S101
41 2 PL
46 2 PL
54 XF1
61 REF
TIE-WRAP BLOCKS 69 2 PL
2724 MAIN P.C.B. COMPONENT SIDE
TOP LIP OF SIDERAILS NOT SHOWN IN THIS VIEW
TOP
8 PL 32
4 PL 13
16 6 PL
7 FRONT PANEL
33
36
40
17

REVISIONS				
ECO	LTR	DESCRIPTION	DATE	APPROVED
	A	RELEASED		
0163	D	QTY OF BINDING POST CHG FROM 6 TO 8	11-11-83	POW
0169	E	SEE ECR 0169 CRE	11-16-83	POW
0151	F	NEW SIDE RAIL WPW	11-22-83	POW
0168	G	NEW BINDING POST W.P.W.	12-6-83	POW
0202	H	CHG (50) TO (52), DELETE (40), ADD #8 LUGS R	12-13-83	R
242	I	NEW SIDE RAIL DWG NO. WPW	12-21-83	R
244	J	ADDED SCREW IN FRONT PANEL CRE	1-4-84	R
487	K	CHANGED PARTS LIST RDN	7-10-84	R

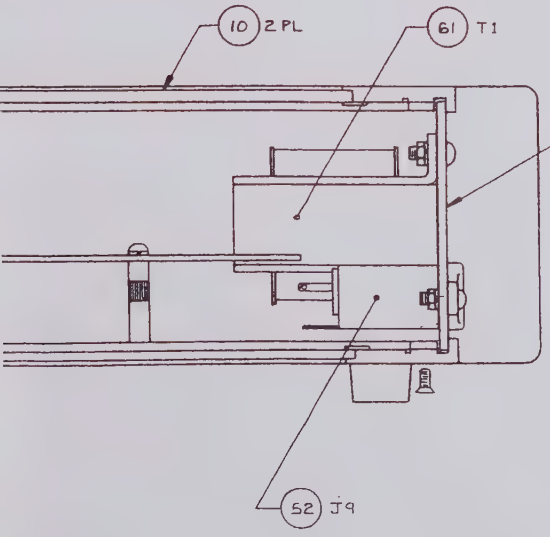


INSIDE VIEW OF REAR PANEL

SIDERAILS NOT SHOWN



FRONT VIEW



SIDE VIEW

MATERIAL	DRAWN C.R.E. 3/82	Valhalla Scientific Inc. SAN DIEGO, CALIFORNIA			
	CHECKED R.M. 4/82				
	APPR POW 12/82				
FINISH		2724 ASSEMBLY			
	SCALE 1:1	CODE IDENT NO 53504	SIZE D	DRAWING NO 2724-400	REV K
	SHEET 6 OF 6				

2724-400

Valhalla Scientific Inc.

PARTS LIST

CHASSIS | MODEL 2724A | DWG NO 2724-400 | REV J

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
1											
2	A1		PCB ASSY, MAIN	53504	2724-600	1					
3	A2		PCB ASSY, DISPLAY	53504	2724-601	1					
4											
5	A4		PCB ASSY, KEYBOARD	53504	2724-603	1					
6											
7		4-10470	FRONT PANEL	53504	2724-100	1					Made From 4-10315
8		4-10316	REAR PANEL	53504	2724-201A	1					
9		4-10458	SIDE RAIL	53504	2724-215	2					
10		4-10318	COVER, TOP/BOTTOM	53504	2724-203	2					
11											
12		4-10333	BEZEL	53504	2724-205	4					
13		4-10332	CORNER BLOCK	53504	2724-204	4					
14		4-10413	MAIN PCB SUPPORT	53504	2724-209	2					
15											
16		5-10280	SPACER, SNAP-IN 3/8" LG	83330	4095	6					
17		5-10253	SPACER, 1" LG x 1/4" RD	83330	2104	6					
18											
19											
20											
21											
22		5-10288	SPACER 1/2" LG x 1/4" RD	83330	8503	4					
23		5-10282	SPACER 1/4" LG x 1/4" RD	83330	2130	6					

NOTES:

Valhalla Scientific Inc.	PARTS LIST	CHASSIS	MODEL 2724A	DWG NO 2724-400	REV J

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
24											
25											
26											
27			HARDWARE:								
28											
29			SCREW,PHIL PAN ST.ST.		8-32 x 1/2"	4					
30			SCREW,PHIL PAN ST.ST.		6-32 x 9/16"	18					
31			SCREW,82° FLAT ST.ST.		6-32 x 3/8"	12					
32			SCREW, 82° FLAT ST.ST.		6-32 x 1/2"	8					
33			SCREW,PHIL,PAN BLACK		6-32 x 9/16"	2					
34											
35			SCREW,PHIL,PAN,ST.ST.		4-40 x 1/2"	2					
36			SCREW,PHIL,PAN,ST.ST.		6-32 x 1 1/4"	10					
37											
38		5-10086	WASHER, GROUND LUG	83330	1412-6	1					
39			WASHER, INT. STAR		#8	8					
40			WASHER, SPLIT LOCK		#6	20					
41			WASHER, SPLIT LOCK		#4	2					
42			WASHER, FLAT		#8	4					
43			NUT, HEX		8-32	4					
44											
45			NUT, HEX, RADIO		6-32	2					
46			NUT, HEX		4-40	2					

NOTES:

Valhalla Scientific Inc.	PARTS LIST	CHASSIS	MODEL 2724A	DWG NO 2724-400	REV J

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
47											
48											
49	J1,2,5,6	5-10191	BINDING POST, RED	Pomona	3770-2	4					
50	J3,4,7,8	5-10190	BINDING POST, BLACK	Pomona	3770-0	4					
51											
52	J9	5-10166	LINE FILTER	14655	APF 600 CEE	1					
53		5-10067	LINE CORD	70903	17250	1					
54	XF1	5-10018	FUSE- HOLDER	75915	453004A	1					
55	F1	5-04007	FUSE, 500mA	75915	500mA SLO-BLO	1					115v UNIT
56	F1	5-04010	FUSE, 250mA	75915	250mA SLO-BLO	1					230v UNIT
57	S101	5-03017	115/230v SWITCH	82389		1					
58	S102	5-03062	SWITCH, KEYLOCK			1					
59	S103	5-03061	SWITCH, POWER	SHADOW	ZFNE152UEE11010106B	1					
60											
61	T1	4-20035	TRANSFORMER	53504	2724-010	1					
62											
63											
64		5-10015	RUBBER FEET, WHITE	83330		4					
65											
66			RING LUG, #8	06383	PV20-8R (20GA)	8					
67											
68		5-10019	CABLE TIE, 31/2" LG	16956		13					
69		5-10261	CABLE TIE BLOCK	06383	AMB25-A	2					

NOTES:

Valhalla Scientific Inc.

PARTS LIST

CHASSIS | MODEL 2724A | DWG NO 2724-400 | REV J

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
70											
71			WIRE:								
72											
73											
74			BLACK 4 FT.		20 AWG TEFLON	1					
75			RED 4 FT.		20 AWG TEFLON	1					
76			WHITE 4 FT.		20 AWG TEFLON	1					
77			GREEN 4 FT.		20 AWG REFLON	1					

NOTES: SHEETS 5 and 6 ARE ASSEMBLY DRAWINGS

Valhalla Scientific Inc.

PARTS LIST

MAINTENANCE KIT

MODEL 2724A

DWG NO 2724-403

REV B

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
1			MAINTENANCE KIT		2724-403	X					
2											
3		4-10128	PAC-TEC-CASE	LaFrance	CM6-225T	1					
4		4-10128	FEET	LaFrance	60221	4					
5		4-10128	SCREWS	LaFrance		2					
6		4-10435	FRONT PANEL	53504	2724-211A	1					
7		4-10436	REAR PANEL	53504	2724-212A	1					
8		4-10434	MAINTENANCE COVER	53504	2724-210A	1					
9											
10		5-03078	SWITCH ROTARY	Centralab	PSA-211	1					
11		5-10190	BINDING POST, BLK	Pomona	3770-0	6					
12		5-10191	BINDING POST, RED	Pomona	3770-2	6					
13		5-10256	KNOB, BLK	Alco	AS1-452-W3-402	1					
14		5-10257	SKIRT, POINTER	Alco	AW5-582	1					
15			NUT, HEX, PANEL		3/8-32 (1/32 THK)	2					
16			WIRE TEFLON 20 AWG	81349	BLK, 20 AWG, 48"	1					
17			WIRE TEFLON 20 AWG	81349	RED, 20 AWG, 48"	1					
18											
19											
20											
21		5-10019	TY-WRAP BLOCK	Panduit	ABM25-A	2					
22		5-10261	TY-WRAP 3 1/2" LG.	Panduit	WRN4	2					
23											

NOTES: SHT 1of 1 IS DWG.

Valhalla Scientific Inc.

PARTS LIST

MAIN PCB ASSY

MODEL 2724A

DWG NO 2724-600

REV G

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
1											
2		4-30081	PCB MAIN	53504	2724-700	1					
3											
4	R109, 116, 128	1-01041	RES, 1K 1/4W 5%	81349	RC07GF102J	7					
	207,409,706,707										
5	R326,104,110,111	1-01081	RES, 100K 1/4W 5%	81349	RC07GF104J	9					
	117,118,205,310,319										
6	R105, 102	1-01100	RES, 1M1/4W, 5%	81349	RC07GF105J	2					
8	R108	1-01128	RES, 1000M, 1/4W 5%	81349	RC07GF108J	1					
9	R101,204,210,314	1-01061	RES, 10K 1/4W 5%	81349	RC07GF103J	15					
	320,328,401,402	411,501,502,503,504,505,602									
10	R113, 201	1-10198	RES, 10K, 1%, 10ppm/°C	PRP	1/4W	2					
11	R114	1-30018	1000/1 DIVIDER SET	CADDOCK	1776-14	1					
12	R103,107,112,115	1-01021	RES,100 1/4W 5%	81349	RC07GF101J	7					
	119,312,506										
13	R120	1-10160	RES 10K 1W 5%	81349	RC32GF103K	1					
14	R121	1-20113	RES 90K PRECISION W/W	Ultronix	2724-011	1					
15	R122	1-20112	RES 9K PRECISION W/W	Ultronix	2724-011	1					
16	R123	1-20111	RES 900 PRECISION W/W	Ultronix	2724-011	1					
17	R124	1-20110	RES 100 PRECISION W/W	Ultronix	2724-011	1					
18	R126	1-20114	RES 1M PRECISION W/W	Ultronix	2724-011	1					

NOTES: SHT. 9 of 9 IS ASSY DWG.

Valhalla Scientific Inc.	PARTS LIST		MODEL 2724A	DWG NO 2724-600	REV G

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	I	N	I	N		REMARKS
19	R25	1-20115	Res 9M 1%	CADDOCK	TF050R-9M-5ppm	1					
20	R127,316	1-01007	RES 10 1/4W 5%	81349	RC07GF100J	2					
21	R202	1-01119	RES 10M 1/4W 5%	81349	RC07GF106J	1					
22	R203	1-10161	RES 47.5K 1% 50ppm	81349	RN60	1					
	R106	1-01053	RES 4.7K 1/4W 5%	81349	RC07GF472J	1					
23	R206	1-10199	RES 15K 1% 10ppm/°C	PRP	1/4W	1					
24	R208,209	1-01007	RES 10 1/4W 5%	81349	RC07GF100J	2					
25	R315	1-01082	RES 120K 1/4W 5%	81340	RC07GF124J	1					
26	R302	1-01056	RES 6.2K 1/4W 5%	81349	RC07GF622J	1					
27	R303	1-01050	RES 3.3K 1/4W 5%	81349	RC07GF332J	1					
28	R304	1-01043	RES 1.5K 1/4W 5%	81349	RC07GF152J	1					
29	R305	1-01038	RES 750 1/4W 5%	81349	RC07GF751J	1					
30	R410,311	1-01051	RES 3.9K 1/4W 5%	81349	RC07GF392J	2					
31	R323	1-01045	RES 2K 1/4W 5%	81349	RC07GF202J	1					
32	R309	1-10162	RES 100K 1% 50ppm/°C	81349	RN60	1					
33	R313,322,329	1-01033	RES 470 1/4W 5%	81349	RC07GF471J	3					
34	R317	1-10200	RES 249K, 1%	81349	RN60C2493F	1					
35	R318	1-10201	RES 45.3K 1% 50ppm/°C	81349	RN60C	1					
36	R321,327	1-01026	RES 220 1/4W 5%	81349	RC07GF221J	2					
37	R324,325	1-10011	RES 40.2K 1%	81349	RN60	2					
38	R403-408	1-01030	RES 330 1/4W 5%	81349	RC07GF331J	6					
39	R601	1-10165	RES 2K 1W 5%	81349	RC32GF202J	1					
	R330	1-01047	RES 2.4K 1/4W 5%	81349	RC07GF242J	1					

NOTES:

Valhalla Scientific Inc. | PARTS LIST | MAIN PCB ASSY | MODEL 2724A | DWG NO 2724-600 | REV G

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
40	C101,104,	2-60002	CAP, MYLAR 0.1µ 100v			7					
	105, 107, 108	203, 301									
41	C103,106,303	2-20013	CAP, MICA, 100p	81349	CM05FD101J03	5					
	304, 305										
42	C109, 110	2-30004	CAP, TANT, 1µ, 25v	05397	T390A105M025AS	2					
43	C302	2-90001	CAP, POLYC, 0.05µ			1					
44	C201,503,504,610	2-30002	CAP,TANT, 33µ, 10v	05397	T390D336M010AS	4					
	C102	2-90002	CAP, POLYC, 5 ufd		625B1A504J	1					
45	C501, 502	2-20019	CAP, MICA, 200p	81349	CM05FD201J03	2					
46	C202	2-10002	CAP, CERM, 470p			1					
47	C601, 604	2-40013	CAP, ALUM, 470µ, 50v	I.C.	477TTA050B	2					
48	C602	2-40016	CAP, ALUM, 22000µ, 10v	I.C.	229TTA010B	1					
49	C603	2-30005	CAP, TANT, 220µ, 10v	05397	T390F227M010AS	1					
50	C605, 606	2-40017	CAP, ALUM, 2200µ, 35v	I.C.	228TTA035B	2					
51	C607	2-40004	CAP, ALUM, 2200µ, 16v	I.C.	228TTA016B	1					
52	C612, 613, 611	2-30001	CAP, TANT, 10µ,25v	05397	T390C106M025AS	3					
53	C608, 609	2-40014	CAP, ALUM, 100µ,25v	I.C.	107TT025B	2					
54	C901-923	2-60004	CAP, MYLAR, 0.01µ								
	C204, C112	2-20018	CAP, MICA, 33pF	Sprague	CM05ED330J03	2					
55	RV201, 101-103	1-50028	RES, VAR, 50KΩ	80294	68WR-50K	4					
	RV301	1-50040	RES, VAR, 5KΩ	73138	68WR-5K	1					
	C111	2-90005	CAP, POLYC, 0.1µ,100v		625B1A104J	1					

NOTES:

Valhalla Scientific Inc. | PARTS LIST | MAIN PCB ASSY | MODEL 2724A | DWG NO 2724-600 | REV G

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
59	D101-104,607	3-20003	10v, 10%, 400mW ZENER	Moto.	1N5240	5					
60											
61	D401-409, 501	3-20000	DIODE	04713	1N4148	10					
62	D203, 204	3-20029	15v, 10%, 5W ZENER	04713	1N5352A	2					
63	D601,604	3-20027	100v, 1A BRIDGE	04713	3N247	2					
64	D602, 603	3-20021	20v, 3A DIODE	04713	1N5821	2					
65	D605, 606	3-20002	100v, 1A DIODE	04713	1N4001	2					
69	TR201,301,302	3-10000	N-CHANNEL JFET SWITCH	27014	U1899E	3					
70	TR303,304,701	3-10010	PNP TRANSISTOR	04713	2N4402	3					
71	TR401-406	3-10026	N-CHANNEL MOS	SILICONIX	VN10KM	6					
74	RLA,C,D,E,H,J,	5-03012	RELAY, 1 FORMC, 5v	SIGMA	PRMA1A05	7					
	L										
75	RLB	5-03067	RELAY, 4 pole c/o	P.B.	R11-E2-V1-2K	1					
76	RLF	5-03068	RELAY	COTO	CR3402-5-82	1					
77	RLG	5-03088	RELAY, 4 pole c/o	P.B.	R10-E2-Z4-J2-5K	1					
78	RLK, M	5-03072	RELAY, 2 pole c/o	AROMAT	DS2E-DC5V	2					

NOTES:

Valhalla Scientific Inc.

PARTS LIST

MAIN PCB ASSY | MODEL 2724A | DWG NO 2724-600 | REV G

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
79	Y501	5-02002	12-8007MHZ XTAL		HC18-12-8007MHz	1					
81	SK3	5-10294	SOCKET, DIL, 20-WAY			1					
82	X1C520-523	5-10293	SOCKET, DIL, 18-WAY			4					
83	X1C519	5-10295	SOCKET, DIL, 28-WAY			1					
84	X1C518	5-10246	SOCKET, DIL, 40-WAY			1					
85	SK2	5-10310	SOCKET, 10-WAY	MOLEX	22-25-2016	6					
90	IC101,103	3-30111	CHOPPER AMP	32293	ICL 7650 IJD	2					
91	IC102,204,308	3-30090	OP AMP BIFET	27014	LF356N	4					
	310										
92	IC104	3-30328	OP AMP BIFET	B-B	OPA103AM	1					3-30315 May be Used
93	IC201	3-30329	MDAC 12-BIT	A.D.	7541	1					
94	IC203	3-30167	MDAC 12-BIT	A.D.	7521L or 7531L	1					3-30324 may ~~be used~~
95	IC202,205,302	3-30170	OP-AMP, LOW NOISE	PM1	OP-07DP	5					
	304, 306										
96	IC206	3-30085	+8v REGULATOR, 500mA		7808	1					
97	IC207	3-30190	CURRENT BOOSTER	04713	MC1438R	1					

NOTES:

Valhalla Scientific Inc.	PARTS LIST	MAIN PCB ASSY	MODEL 2724A	DWG NO 2724A-600	REV G

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N			REMARKS
99	IC301,303	3-30330	8 TO 1 ANALOG MUX	SILICONIX	DG508A	2				
100	IC305	3-30073	COMPARATOR	27014	LF311H	1				
101	IC309,414	3-30173	HEX INVERTOR/BUFFER		SN7406N	2				
102										
103	IC401-408,	3-30185	QUAD OPTO-ISOLATOR	LITRONIX	ILQ-74	11				
	411,412,413									
104	IC409	3-30093	OPTO-ISOLATOR	HP	HCPL-2601	1				
105	IC410	3-30186	DUAL OPTO-ISOLATOR	HP	HCPL-2630	1				
106										
107	IC501,502	3-30011	DUAL D-TYPE F-F		SN7474N	2				
108	IC503	3-30010	QUAD EXCLUSIVE-OR		SN7486N	1				
109	IC504	3-30174	QUAD OR		SN7432N	1				
110	IC505	3-30175	DUAL MONOSTABLE		SN74LS123N	1				
111	IC506,507,530	3-30176	DUAL 4-BIT COUNTER		SN74LS393N	3				
112	IC508,509,	3-30177	OCTAL D-TYPE		SN74LS374N	9				
	512-517,526									
113	IC510	3-30156	OCTAL 3-STATE BUFFER		SN74LS541N	1				
114	IC511	3-30162	OCTAL TRANSCEIVER		SN74LS245N	1				
115	IC518	3-30187	1.5MHz MPU	MOTO	MC68A09	1				
116	IC519	3-50019	8Kx8 UVEPROM,350nS		3-30198 (2764)	1				
117	IC520,521	3-30188	1Kx4 RAM, 350nS		2114L-35	2				
118	IC522,523	3-30189	256x4 NOVRAM	X1COR	2212	2				

NOTES:

Valhalla Scientific Inc.	PARTS LIST	MAIN PCB ASSY	MODEL 2724A	DWG NO 2724-600	REV G

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
119	IC524	3-30155	3 TO 8 DECODER		SN74LS138N	1					
120	IC525,705	3-30182	4 TO 16 DECODER		SN74154N	2					
122	IC527	3-30199	OSCILLATOR		SN74LS624N	1					
123	IC528	3-30181	DUAL BCD COUNTER		SN74LS490N	1					
124	IC529	3-30180	MODULO 12 COUNTER		SN74LS92N	1					
125											
126	IC531	3-30002	QUAD 2 INPUT, NAND		SN74LS00N	1					
127	IC532	3-30095	DUAL D-TYPE F-F		SN7474N	1					
128											
130	IC701-704	3-30183	OCTAL DISPLAY DRIVER		DI 513	4					
131	IC706,707,708	3-30184	HEX INVERTOR		SN74LS04N	3					
132	IC307	3-30122	VOLTAGE REFERENCE		LM399H	1					
135	IC601	3-30042	+5v REGULATOR 1 1/2A		7805KC	1					
136	IC602	3-30171	+18vREGULATOR 1/2A		7818T	1					
137	IC603	3-30172	-18v REGULATOR 1/2A		7918T	1					
138	IC604, 605	3-30034	+5v REGULATOR 1/2A		7805	2					
139	IC105	3-30168	+5v REGULATOR 100mA		LM340LAZ-5	1					
140	IC606, IC106	3-30169	-5v REGULATOR 100mA		LM320LZ-5	2					

NOTES:

Valhalla Scientific Inc.	PARTS LIST	MAIN PCB ASSY	MODEL 2724A	DWG NO 2724-600	REV G

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
142	RN401-405	1-40001	NETWORK, 8x470Ω		316B-471	5					
143	RN406-408	1-40003	NETWORK, 15x10KΩ		316A-103	3					
144											
145	R301	1-01062	RES 12K 1/4W 5%	81349	RC07GF123J	1					
146	R306	1-01031	RES 390 1/4W 5%	81349	RC07GF391J	1					
147	R307,308	1-01025	RES 200 1/4W 5%	81349	RC07GF201J	2					
148											
149											
150		5-10007	TURRET TERMINAL	88245	1300B	2					
151											
152			SCREW PHIL PAN St.St.		4-40x1/4"	3					
153			SCREW PHIL PAN St.St.		6-32x3/8"	4					
154			WASHER, SPLIT LOCK		#6	4					
155			NUT, RADIO, HEX		6-32	4					
156			NUT, RADIO, HEX		4-40	3					
157			WASHER, SPLIT LOCK		#4	3					
158	HIC602-604	5-10211	HEATSINK, TO-220		THM6106-14	3					
159	HIC601	5-10058	HEATSINK, TO-3		THM6004-2	1					
160	HIC207	5-10477	HEATSINK, TO-66IC	53504	2724-214	1					
161											
162		5-10449	TY WRAP 14"Lg.,150Wd.	PANDUIT	PLT41-M	1					
163											
164											

NOTES: SHEET 9 IS THE ASSY. DRAWING

Valhalla Scientific Inc.

PARTS LIST

MODEL	DWG NO	REV
2724-CPR	2724-404	A

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N			REMARKS
1			COMPLETE 2724			1				
2										
3	DELETE	IC207	BUFFER			1				
4	DELETE	HEATSINK	MODIFIED			1				
5	DELETE	SCREWS	6-32X3/8 LG			2				
6	DELETE	HEXNUTS	6-32 RADIO HEX			2				
7	DELETE	WASHERS	#6 INT STAR			2				
8	DELETE	RLK	DPDT-5V 5-03072			1				
9	DELETE	KEYCAP	"4-WIRE"			1				
10	DELETE	KEYCAP	"SLOW MODE"			1				
11										
12	ADD	5-03083	RELAY	Aromat		1				
13	ADD	5-03087	KEYCAP SET	Val	2724-216	1				
14	ADD		30 AWG KYNAR WIRE			AR				
15	ADD		18 AWG WIRE			AR				
16	ADD		5 MIN EPOXY			AR				

NOTES:

Valhalla Scientific Inc.	PARTS LIST	KEYBOARD ASSY.	MODEL 2724A	DWG NO 2724-603	REV D

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY. I	QTY. N	I	N		REMARKS
1											
2											
3		4-30085	PCB KEYBOARD	53504	2724-703	1					
4											
5	DS1-7	5-01011	LED, RED	28480	5082-4655	1					
6											
7	S1-29	5-03060	SWITCH	SCHADOW	71882	29					
8		5-03085	KEYCAPS, ENGRAVED	53504	2724-208	1					
9											
10		5-10446	SPACER 5/16 RD 1/4 LG #10	RAF	1155-10-A-0	2					
11		5-10447	SPACER 1/4 RD 1/8 LG #8 SWAGE	RAF	1531-E-6-A-0	2					
xx											
12		5-10198	SPACER 1/8" LG x 1/4" RD	RAF	1122-4-N	7					
13											
14		4-10355	STIFFENER BAR	53504	2724-206	2					
15			SCREW PHIL PAN St.St.		4-40 x 1/4"	4					
16			NUT, RADIO HEX		4-40	4					
17			WASHER, SPLIT LOCK		#4	4					
18	PL3	5-10332	WAFER, 10-WAY	C.A.	CAS-10SP-230T-1.23	2					
19											
20			LOCKTITE			A/R					
21											
22											

NOTES: SHEET 2 IS THE ASSY. DRAWING

Valhalla Scientific Inc.

PARTS LIST

DISPLAY PCB | MODEL 2724A | DWG NO 2724-601 | REV A

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
1	D701-704	3-20000	DIODE		1N4148	4					
3	DS701	5-01022	VFD 16 x 16 seg.		FG169B2	1					
8	IC703,704	3-30164	HEX BUFFER		SN7407N	2					
10	R701	1-01081	RES 100K 1/4W 5%		RC07GF104J	1					
11	R702	1-01021	RES 100 1/4W 5%		RC07GF101J	1					
12	R703-706	1-01041	RES 1K 1/4W 5%		RC07GF102J	4					
14		4-30082	PC BOARD		2724-701	1					
16	RN701, 702	1-40000	NETWORK 15 x100K		316A-104	2					
18	PL2	5-10332	WAFER ASSY, 10-WAY	CA	CA-S10SP-230T-1.23	6					
19	SK3	5-10321	SOCKET, 10-WAY	MOLEX	22-14-2101	2					

NOTES: SHEET 2 IS THE ASSY. DRAWING.

Valhalla Scientific Inc.

PARTS LIST

IEEE INTERFACE | MODEL 2724 | DWG NO 2724-602 | REV C

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
1											
2	C801	2-10006	CAP. .01µf,50V,CER		8121-050-651-103M	1					
3											
4	D801-804	3-20000	DIODE	04713	IN4148	4					
5											
6	IC801	3-30162	Octal Bus Transceiver	01295	74LS245	1					
7	IC802	3-30158	GPIA	04713	MC68488P	1					
8	IC803& 804		OCTAL BUS TRANSCEIVER	04713	MC3447P3	2					
9		3-30157 or	P.C.B. ASSY.	53504	2724-604	1					
10	RN801	1-40003	RES. NETWORK, 10K	01121	316A103	1					
11											
12	PL801	5-10271	CABLE ASSY.	53504	2724-050	1					
13		5-10217	SPACER, 1/4Dia x 1/4LG	83330	2101	5					
14		4-30083	PC BOARD, IEEE	53504	2724-702	1					
15			WASHER, SPLIT LOCK		#6	5					
16	SK801	5-10268	RECEPTACLE	Amphenol	57-20240-14	1					
17			NUT, HEX		6-32	5					
18		5-10244	CONNECTOR, CHAMPS	AMP	552633-3	1					
19											
20			WASHER, SPLIT LOCK		#8	2					
21			NUT, HEX		4-40	2					
22			WASHER, FLAT		#4	2					
23			SCREW, PHIL, FLAT HD,82°		6-32x 5/8	5					

NOTES:

Federal Supply Codes for Manufacturers

00656
Aerovox Corp.
New Bedford, Massachusetts

00686
Film Capacitors, Inc.
Passaic, New Jersey

00779
AMP Inc.
Harrisburg, Pennsylvania

00853
Sangamo Electric Company
Pickens, South Carolina

01121
Allen-Bradley Co.
Milwaukee, Wisconsin

01255
Litton Industries, Inc.
Beverly Hills, California

01281
TRW Electronic Comp.
Semiconductor Operations
Lawndale, California

01295
Texas Instruments, Inc.
Dallas, Texas

01686
RCL Electronics Inc.
Manchester, New Hampshire

02114
Ferroxcube Corp.
Saugerties, New York

02131
General Instrument Corp.
Westwood, Maine

02799
Areo Capacitors, Inc.
Chatsworth, California

03508
General Electric Co.
Syracuse, New York

03797
Genisco Technology Corp.
Compton, California

03877
Transistron Electronic Corp.
Wakefield, Massachusetts

03911
Clairex Corp.
Mt. Vernon, New York

04009
Arrow Hart Inc.
Hartford, Connecticut

04217
Essex International Inc.
Anaheim, California

04222
AVX Corp.
Myrtle Beach, Florida

04423
Telonic Industries
Laguna Beach, California

04713
Motorola Inc
Phoenix, Arizona

04946
Standard Wire & Cable
Los Angeles, California

05276
Pomona Electronics Co., inc.
Pomona, California

05277
Westinghouse Electric Corp.
Youngwood, Pennsylvania

05397
Kemet, Union Carbide Corp.
New York, New York

05574
Viking Industries
Chatsworth, California

05820
Wakefield Engineering Inc.
Wakefield, Massachusetts

06001
General Electric Co.
Columbia, South Carolina

06383
Panduit Corp.
Tinley Park, Illinois

06473
Bunker Ramo Corp.
Chatsworth, California

06555
Beede Electrical Instrument Co.
Penacook, New Hampshire

06743
Clevite Corp.
Cleveland, Ohio

07088
Kelvin Electric Company
Van Nuys, California

07256
Silicon Transistor Corp.
Chelmsford, Massachusetts

07263
Fairchild Semiconductor
Mountain View, California

07344
Bircher Co., Inc.
Rochester, New York

07597
Burndy Corp.
Rochester, New York

07716
I R C Incorporated
Burlington, Iowa

07910
Teledyne Semiconductor
Hawthorne, California

08065
Accurate Rubber and Plastics Co.
San Diego, California

08261
Spectra Strip Corp.
Garden Grove, California

08530
Reliance Mica Corp.
Brooklyn, New York

08806
General Electric Co.
Cleveland, Ohio

09026
Babcock Electronics Corp.
Costa Mesa, California

09214
G. E. Co. Semi-Conductor
Auburn, New York

09353
C and K Components
Watertown, Massachusetts

09922
Burndy Corp.
Norwalk, Connecticut

09969
Dale Electronics Inc.
Yankton, S. Dakota

11236
CTS of Berne
Berne, Indiana

11403
Best Products Co.
Chicago, Illinois

11503
Keystone Columbia Inc.
Warren, Michigan

11532
Teledyne Relays
Hawthorne, California

11711
General Instrument Corp.
Hicksville, New York

12014
Chicago Rivet & Machine Co.
Bellwood, Illinois

12060
Diodes, Inc.
Chatsworth, California

12136
Philadelphia Handle Co.
Camden, New Jersey

12405
Hysol Corporation
El Monte, California

12406
Elpac, Incorporated
Fullerton, California

12615
U.S. Terminals Inc.
Cincinnati, Ohio

12617
Hamlin Inc.
Lake Mills, Wisconsin

12697
Clarostat Mfg Co.
Dover, New Hampshire

12969
Unitrode Corp.
Watertown, Massachusetts

13103
Thermalloy Co., Inc.
Dallas, Texas

13327
Solitron Devices Inc.
Tappan, New York

13454
Texas Crystals
River Grove, Illinois

13511
Amphenol Cadre Div.
Los Gatos, California

13606
Use 56289
Sprague Electric Co.
Concord, New Hampshire

14099
Semtech Corp.
Newbury Park, California

14655
Cornell-Dublier Electronics
Newark, New Jersey

14752
Electro Cube Inc.
San Gabriel, California

14936
General Instrument Corp.
Hicksville, New York

15801
Fenwal Electronics Inc.
Framingham, Massachusetts

15818
Teledyne Semiconductors
Mountain View, California

15849
Useco Inc.
Van Nuys, California

15898
International Business
Machines Corp.
Essex Junction, Vermont

16332
Replaced by 28478

16473
Cambridge Scientific Ind.
Cambridge, Maryland

16758
Delco Electronics
Kokomo, Indiana

17856
Siliconix, Inc.
Santa Clara, California

18324
Signetics Corp.
Sunnyvale, California

Federal Supply Codes for Manufacturers (cont.)

18612
Vishay Intertechnology Inc.
Malvern, Pennsylvania

18722
R C A
Mountaintop, Pennsylvania

18927
GTE Sylvania Inc.
Titusville, Pennsylvania

21604
Bucheye Stamping Co.
Columbus, Ohio

21845
Solitron Devices Inc.
Riveria Beach, Florida

22767
ITT Semiconductors
Palo Alto, California

23936
Pamotor Div.
Burlingham, California

24355
Analog Devices Inc.
Norwood, Massachusetts

24655
General Radio
Concord, Massachusetts

25088
Siemen Corp.
Isilen, New Jersey

25403
Amperex Electronic Corp.
Slatersville, Rhode Island

25684
Victoreen Instrument Co., Inc.
Oak Lawn, Illinois

27014
National Semiconductor Corp.
Santa Clara, California

27556
IMB Electronic Products
Santa Fe Springs, California

27264
Molex Products
Downers Grove, Illinois

28213
Minnesota Mining & Mfg. Co.
St. Paul, Minnesota

28480
Hewlett Packard Co.
Palo Alto, California

29083
Monsanto Co., Inc.
Santa Clara, California

29604
Stackpole Components Co.
Raleigh, North Carolina

30323
Illinois Tool Works, Inc.
Chicago, Illinois

30983
Electra/Midland
San Diego, California

32539
Mura Corp.
Great Neck, New York

32897
Erie Technological Products, Inc.
Carlisle, Pennsylvania

32997
Bourns Inc.
Riverside, California

33173
General Electric Co.
Owensboro, Kentucky

34333
Silicon General
Westminister, California

34335
Advanced Micro Devices
Sunnyvale, California

34802
Electromotive Inc.
Kenilworth, New Jersey

37942
P.R. Mallory & Co., Inc.
Indianapolis, Indiana

43543
Nytronics Inc.
Geneva, New York

44655
Ohmite Mfg. Co.
Skokie, Illinois

49671
RCA Corp.
New York, New York

49956
Raytheon Company
Lexington, Massachusetts

50088
Mostek Corp.
Carrollton, Texas

50579
Litronix Inc.
Cupertino, California

51605
Scientific Components Inc.
Linden, New Jersey

53021
Sangamo Electric Co.
Springfield, Illinois

53504
Valhalla Scientific, Inc.
San Diego, California

54294
Cutler-Hammer Inc.
Selma, North Carolina

55026
Simpson Electric Co
Elgin, Illinois

56289
Sprague Electric Co.
North Adams, Massachusetts

58474
Superior Electric Co.
Bristol, Connecticut

63743
Ward Leonard Electric Co., Inc.
Mount Vernon, New York

65092
Weston Instruments Inc.
Newark, New Jersey

70563
Amperite Company
Union City, New Jersey

70903
Belden Corp.
Geneva, Illinois

71279
Cambridge Thermionic Corp.
Cambridge, Massachusetts

71400
Bussmann Mfg.
Saint Louis, Missouri

71450
CTS Corp.
Elkhart, Indiana

71468
ITT Cannon Electric Inc.
Santa Ana, California

71482
Clare, C.P. & Co.
Chicago, Illinois

71590
Centrelab Electronics
Milwaukee, Wisconsin

71707
Coto Coil Co., Inc.
Providence, Rhode Island

71744
Chicago Miniature Lamp Works
Chicago, Illinois

71785
TRW Electronics Components
Chicago, Illinois

72005
Wilber B. Driver Co.
Newark, New Jersey

72259
Nytronics Inc.
Pelham Manor, New Jersey

72619
Dialight Div.
Brooklyn, New York

72982
Erie Tech. Products Inc.
Erie, Pennsylvania

73138
Bechman Instrument Inc.
Helipot Division
Fullerton, California

73445
Amperex Electronic Corp.
Hicksville, New York

73734
Federal Screw Products, Inc
Chicago, Illinois

73899
JFD Electronics Co.
Brooklyn, New York

73949
Guardian Electric Mfg. Co
Chicago, Illinois

74276
General Instrument Corp.
Neptune, New Jersey

74306
Piezo Crystal Co.
Carlisle, Pennsylvania

74970
Johnson E.F., Co.
Waseca, Minnesota

75042
TRW Electronics Components
IRC Fixed Resistors
Philadelphia, Pennsylvania

75378
CTS Knights Inc.
Sandwich, Illinois

75382
Kulka Electric Corp.
Mount Vernon, New York

75915
Littlefuse Inc.
Des Plaines, Illinois

76055
Mallory Controls
Frankfort, Indiana

76493
J.W. Miller Company
Los Angeles, California

76854
Oak Industries Inc.
Crystal Lake, Illinois

77342
Potter & Brumfield Div.
Princeton, Indiana

77638
General Instrument Corp.
Rectifier Division
Brooklyn, New York

78488
Stackpole Carbon Co.
Saint Marys, Pennsylvania

78553
Eaton Corp.
Cleveland, Ohio

80031
Electro-Midland Corp.
Mepco Div.
Norristown, New Jersey

56289
Sprague Products
North Adams, Massachusetts

80294
Bourns Inc., Instrument Div.
Riverside, California

81073
Grayhill, Inc
La Grange, Illinois

Federal Supply Codes for Manufacturers (cont.)

81095
Triad Transformer Corp.
Venice, California

81312
Winchester Electronics
Div. of Litton Industries Inc.
Oakville, Connecticut

81483
International Rectifier Corp.
Los Angeles, California

81741
Chicago Lock Co.
Chicago, Illinois

82389
Switchcraft Inc.
Chicago, Illinois

82877
Rotron Inc.
Woodstock, New York

82879
ITT Royal Electric Div.
Pawtucket, Rhode Island

83003
Varo Inc.
Garland, Texas

83298
Bendix Corp.
Eatontown, New Jersey

83330
Herman H. Smith, Inc.
Brooklyn, New York

83594
Burroughs Corp.
Plainfield, New Jersey

83740
Union Carbide Corp.
New York, New York

84171
Arco Electronics
Great Neck, New York

84411
TRW Electronic Components
Ogallala, Nebraska

84613
Fuse Indicator Corp.
Rockville, Maryland

84682
Essex International Inc.
Peabody, Massachusetts

86684
Radio Corp. of America
Harrison, New Jersey

88219
Gould Inc.
Trenton, New Jersey

88245
Litton Systems Inc.
Useco Div.
Van Nuys, California

88419
Cornell-Dubilier Electronic Div.
Fuquay-Varian, North Carolina

89730
G.E. Co.
Newark, New Jersey

90201
Mallory Capacitor Co.
Indianapolis, Indiana

56365
Square D Co.
Chicago, Illinois

90303
Mallory Battery Co.
Tarrytown, New York

91094
Essex International Inc.
Newmarket, New Hampshire

91293
Johanson Mfg. Co.
Boonton, New Jersey

91506
Augat Inc.
Attleboro, Massachusetts

91637
Dale Electronics Inc.
Columbus, Nebraska

91662
Elco Corp.
Willow Grove, Pennsylvania

71468
Gremar Mfg. Co., Inc.
ITT Cannon/Gremar
Santa Ana, California

91802
Industrial Devices, Inc.
Edgewater, New Jersey

91833
Keystone Electronics Corp.
New York, New York

91929
Honeywell Inc.
Micro Switch Div.
Freeport, Illinois

92194
Alpha Wire Corp.
Elizabeth, New Jersey

93332
Sylvania Electric Products
Woburn, Massachusetts

94988
Wagner Electric Corp.
Tung-Sol Div.
Newark, New Jersey

95146
Alco Electronic Products Inc.
Lawrence, Massachusetts

95275
Vitramon Inc.
Bridgeport, Connecticut

95303
RCA Corp.
Receiving Tube Div.
Cincinnati, Ohio

95348
Gordo's Corp.
Bloomfield, New Jersey

95712
Bendix Corp.
Franklin, Indiana

97913
Industrial Electronic
Hardware Corp.
New York, New York

97945
Penwalt Corp.
SS White Industrial Products Div.
Piscataway, New Jersey

98278
Malco A. Microdot Co., Inc.
Connector & Cable Div.
Pasadena, California

98291
Sealectro Corp.
Mamaroneck, New York

98388
Royal Industries
Products Div.
San Diego, California

98978
IERC
Burbank, California

99120
Plastic Capacitors, Inc.
Chicago, Illinois

99217
Bell Industries Elect.
Burbank, California

99392
STM
Oakland, California

99515
ITT Jennings Monrovia Plant
Monrovia, California

99779
Use 29587
Bunker-Ramo Corp.
Landsdowne, Pennsylvania

99942
Centrelab Semiconductor
El Monte, California

VALHALLA SCIENTIFIC

www.manualsplus.com
1014069